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FRAGMENTS OF SCIENCE

VOL. II

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A SERIES OF DETACHED
ESSAYS, ADDRESSES, AND REVIEWS

BY
JOHN TYNDALL, F.R.S.
AUTHOR OF NEW FRAGMENTS, HEAT AS A MODE OF MOTION,
ON SOUND, RADIANT HEAT, ON FORMS OF WATER,
HOURS OF EXERCISE IN THE ALPS, ETC.

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In the bright sky they perceived an illuminator; in the all-encircling firmament an embracer; in the roar of thunder and in the violence of the storm they felt the presence of a shouter and of furious strikers; and out of the rain they created an Indra, or giver of rain.—MAX MÜLLER.

I.

REFLECTIONS ON PRAYER AND NATURAL LAW.

1861.

AMID the apparent confusion and caprice of natural phenomena, which roused emotions hostile to calm investigation, it must for ages have seemed hopeless to seek for law or orderly relation; and before the thought of law dawned upon the unfolding human mind these otherwise inexplicable effects were referred to personal agency. In the fall of a cataract the savage saw the leap of a spirit, and the echoed thunder-peal was to him the hammer-clang of an exasperated god. Propitiation of these terrible powers was the consequence, and sacrifice was offered to the demons of earth and air.

But observation tends to chasten the emotions and to check those structural efforts of the intellect which have emotion for their base. One by one natural phenomena came to be associated with their proximate causes; the idea of direct personal volition mixing itself with the economy of nature retreating more and more. Many of us fear this change. Our religious feelings are dear to us, and we look with suspicion and dislike on any philosophy, the apparent tendency of which is to dry them up. Probably every change from ancient savagery to our present enlightenment has excited, in a greater or less degree, fears of this kind. But the fact is, that we have not yet determined whether its present form is necessary to the life and warmth of religious feeling. We may err in linking the imperishable with the transitory, and confound the living plant with the decaying pole to which it clings. My object, however, at present is not to argue, but to mark a tendency. We have ceased to propitiate the powers of nature— ceased even to pray for things in manifest contradiction to natural laws. In Protestant countries, at least, I think it is conceded that the age of miracles is past.

At an auberge near the foot of the Rhone glacier, I met, in the summer of 1858, an athletic young priest, who, after a solid breakfast, including a bottle of wine, informed me that he had come up to 'bless the mountains.' This was the annual custom of the place. Year by year the Highest was entreated, by official intercessors, to make such meteorological arrangements as should ensure food and shelter for the flocks and herds of the Valaisians. A diversion of the Rhone, or a deepening of the river's bed, would, at the time I now mention, have been of incalculable benefit to the inhabitants of the valley. But the priest would have shrunk from the idea of asking the Omnipotent to open a new channel for the river, or to cause a portion of it to flow over the Grimsel pass, and down the valley of Oberhasli to Brientz. This he would have deemed a miracle, and he did not come to ask the Creator to perform miracles, but to do something which he manifestly thought lay quite within the bounds of the natural and non-miraculous. A Protestant gentleman who was present at the time smiled at this recital. He had no faith in the priest's blessing; still, he deemed his prayer different in kind from a request to open a new river-cut, or to cause the water to flow up-hill.

In a similar manner the same Protestant gentleman would doubtless smile at the honest Tyrolese priest, who, when he feared the bursting of a glacier dam, offered the sacrifice of the Mass upon the ice as a means of averting the calamity. That poor man did not expect to convert the ice into adamant, or to strengthen its texture, so as to enable it to withstand the pressure of the water; nor did he expect that his sacrifice would cause the stream to roll back upon its source and relieve him, by a miracle, of its presence. But beyond the boundaries of his knowledge lay a region where rain was generated, he knew not how. He was not so presumptuous as to expect a miracle, but he firmly believed that in yonder cloud-land matters could be so arranged, without trespass on the miraculous, that the stream which threatened him and his people should be caused to shrink within its proper bounds.

Both these priests fashioned that which they did not understand to their respective wants and wishes. In their case imagination came into play, uncontrolled by a knowledge of law. A similar state of mind was long prevalent among mechanicians. Many of these, among whom were to be reckoned men of consummate skill, were occupied a century ago with the question of perpetual motion. They aimed at constructing a machine which should execute work without the expenditure of power; and some of them went mad in the pursuit of this object. The faith in such a consummation, involving, as it did, immense personal profit to the inventor, was extremely exciting, and every attempt to destroy this faith was met by bitter resentment on the part of those who held it. Gradually, however, as men became more and more acquainted with the true functions of machinery, the dream dissolved. The hope of getting work out of mere mechanical combinations disappeared: but still there remained for the speculator a cloud-land denser than that which filled the imagination of the Tyrolese priest, and out of which he still hoped to evolve perpetual motion. There was the mystic store of chemic force, which nobody understood; there were heat and light, electricity and magnetism, all competent to produce mechanical motion.[1] Here, then, was the mine in which our gem must be sought. A modified and more refined form of the ancient faith revived; and, for aught I know, a remnant of sanguine designers may at the present moment be engaged on the problem which like-minded men in former ages left unsolved.

And why should a perpetual motion, even under modern conditions, be impossible? The answer to this question is the statement of that great generalisation of modern science, which is known under the name of the Conservation of Energy. This principle asserts that no power can make its appearance in nature without an equivalent expenditure of some other power; that natural agents are so related to each other as to be mutually convertible, but that no new agency is created. Light runs into heat; heat into electricity; electricity into magnetism; magnetism into mechanical force; and mechanical force again into light and heat. The Proteus changes, but he is ever the same; and his changes in nature, supposing no miracle to supervene, are the expression, not of spontaneity, but of physical necessity. A perpetual motion, then, is deemed impossible, because it demands the creation of energy, whereas the principle of Conservation is—no creation, but infinite conversion.

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[1] See Helmholtz: 'Wechselwirkung der Naturkräfte.'

It is an old remark that the law which moulds a tear also rounds a planet. In the application of law in nature the terms great and small are unknown. Thus the principle referred to teaches us that the Italian wind, gliding over the crest of the Matterhorn, is as firmly ruled as the earth in its orbital revolution round the sun; and that the fall of its vapour into clouds is exactly as much a matter of necessity as the return of the seasons. The dispersion, therefore, of the slightest mist by the special volition of the Eternal, would be as much a miracle as the rolling of the Rhone over the Grimsel precipices, down the valley of Hasli to Meyringen and Brientz.

It seems to me quite beyond the present power of science to demonstrate that the Tyrolese priest, or his colleague of the Rhone valley, asked for an 'impossibility' in praying for good weather; but Science *can* demonstrate the incompleteness of the knowledge of nature which limited their prayers to this narrow ground; and she may lessen the number of instances in which we 'ask amiss,' by showing that we sometimes pray for the performance of a miracle when we do not intend it. She does assert, for example, that without a disturbance of natural law, quite as serious as the stoppage of an eclipse, or the rolling of the river Niagara up the Falls, no act of humiliation, individual or national, could call one shower from heaven, or deflect towards us a single beam of the sun.

Those, therefore, who believe that the miraculous is still active in nature, may, with perfect consistency, join in our periodic prayers for fair weather and for rain: while those who hold that the age of miracles is past, will, if they be consistent, refuse to join in these petitions. And these latter, if they wish to fall back upon such a justification, may fairly urge that the latest conclusions of science are in perfect accordance with the doctrine of the Master himself, which manifestly was that the distribution of natural phenomena is not affected by moral or religious causes. 'He maketh His sun to rise on the evil and on the good, and sendeth rain on the just and on the unjust.' Granting 'the power of Free Will in man,' so strongly claimed by Professor Mansel in his admirable defence of the belief in miracles, and assuming the efficacy of free prayer to produce changes in external nature, it necessarily follows that natural laws are more or less at the mercy of man's volition, and no conclusion founded on the assumed permanence of those laws would be worthy of confidence.

It is a wholesome sign for England that she numbers among her clergy men wise enough to understand all this, and courageous enough to act up to their knowledge. Such men do service to public character, by encouraging a manly and intelligent conflict with the real causes of disease and scarcity, instead of a delusive reliance on supernatural aid. But they have also a value beyond this local and temporary one. They prepare the public mind for changes, which though inevitable, could hardly, without such preparation, be wrought without violence. Iron is strong; still, water in crystallising will shiver an iron envelope, and the more unyielding the metal is, the worse for its safety. There are in the world men who would encompass philosophic speculation by a rigid envelope, hoping thereby to restrain it, but in reality giving it explosive force. In England, thanks to men of the stamp to which I have alluded, scope is gradually given to thought for changes of aggregation, and the envelope slowly alters its form, in accordance with the necessities of the time.

The proximate origin of the foregoing slight article, and probably the remoter origin of the next following one, was this. Some years ago, a day of prayer and humiliation, on account of a bad harvest, was appointed by the proper religious authorities; but certain clergymen of the Church of England, doubting the wisdom of the demonstration, declined to join in the services of the day. For this act of nonconformity they were severely censured by some of their brethren. Rightly or wrongly, my sympathies were on the side of these men; and, to lend them a helping hand in their struggle against odds, I inserted the foregoing chapter in a little book entitled 'Mountaineering in 1861.' Some time subsequently I received from a gentleman of great weight and distinction in the scientific world, and, I believe, of perfect orthodoxy in the religious one, a note directing my attention to an exceedingly thoughtful article on Prayer and Cholera in the 'Pall Mall Gazette.' My eminent correspondent deemed the article a fair answer to the remarks made by me in 1861. I, also, was struck by the temper and ability of the article, but I could not deem its arguments satisfactory, and in a short note to the editor of the 'Pall Mall Gazette' I ventured to state so much. This letter elicited some very able replies, and a second leading article was also devoted to the subject. In answer to all, I risked the publication of a second letter, and soon afterwards, by an extremely courteous note from the editor, the discussion was closed.

Though thus stopped locally, the discussion flowed in other directions. Sermons were preached, essays were published, articles were written, while a copious correspondence occupied the pages of some of the religious newspapers. It gave me sincere pleasure to notice that the discussion, save in a few cases where natural coarseness had the upper hand, was conducted with a minimum of vituperation. The severity shown was hardly more than sufficient to demonstrate earnestness, while gentlemanly feeling was too predominant to permit that earnestness to contract itself to bigotry or to clothe itself in abuse. It was probably the memory of this discussion which caused another excellent friend of mine to recommend to my perusal the exceedingly able work which in the next article I have endeavoured to review.

Mr. Mozley's book belongs to that class of writing of which Butler may be taken as the type. It is strong, genuine argument about difficult matters, fairly tracing what *is* difficult, fairly trying to grapple, not with what appears the gist and strong point of a question, but with what really at bottom is the knot of it. It is a book the reasoning of which may not satisfy everyone. . . . But we think it is a book for people who wish to see a great subject handled on a scale which befits it, and with a perception of its real elements. It is a book which will have attractions for those who like to see a powerful mind applying itself, without shrinking or holding back, without trick or reserve or show of any kind, as a wrestler closes body to body with his antagonist, to the strength of an adverse and powerful argument.—TIMES, *Tuesday, June* 5, 1866.

We should add, that the faults of the work are wholly on the surface and in the arrangement; that the matter is as solid and as logical as that of any book within recent memory, and that it abounds in striking passages, of which we have scarcely been able even to give a sample. No future arguer against miracles can afford to pass it over.—SATURDAY REVIEW, *September* 15, 1866.

II.

MIRACLES AND SPECIAL PROVIDENCES.[1]

1867.

IT is my privilege to enjoy the friendship of a select number of religious men, with whom I converse frankly upon theological subjects, expressing without disguise the notions and opinions I entertain regarding their tenets, and hearing in return these notions and opinions subjected to criticism. I have thus far found them liberal and loving men, patient in hearing, tolerant in reply, who know how to reconcile the duties of courtesy with the earnestness of debate. From one of these, nearly a year ago, I received a note, recommending strongly to my attention the volume of 'Bampton Lectures' for 1865, in which the question of miracles is treated by Mr. Mozley. Previous to receiving this note, I had in part made the acquaintance of the work through an able and elaborate review of it in the 'Times.' The combined effect of the letter and the review was to make the book the companion of my summer tour in the Alps. There, during the wet and snowy days which were only too prevalent in 1866, and during the days of rest interpolated between days of toil, I made myself more thoroughly conversant with Mr. Mozley's volume. I found it clear and strong—an intellectual tonic, as bracing and pleasant to my mind as the keen air of the mountains was to my body. From time to time I jotted down thoughts regarding it, intending afterwards to work them up into a coherent whole. Other duties, however, interfered with the complete carrying out of this intention, and what I wrote last summer I now publish, not hoping to be able, within any reasonable time, to render my defence of scientific method more complete.

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[1] *Fortnightly Review*, New Series, vol. i. p. 645.

Mr. Mozley refers at the outset of his task to the movement against miracles which of late years has taken place, and which determined his choice of a subject. He acquits modern science of having had any great share in the production of this movement. The objection against miracles, he says, does not arise from any minute knowledge of the laws of nature, but simply because they are opposed to that plain and obvious order of nature which everybody sees. The present movement is, he thinks, to be ascribed to the greater earnestness and penetration of the present age. Formerly miracles were accepted without question, because without reflection; but the exercise of the 'historic imagination' is a characteristic of our own time. Men are now accustomed to place before themselves vivid images of historic facts; and when a miracle rises to view, they halt before the astounding occurrence, and, realising it with the same clearness as if it were now passing before their eyes, they ask themselves, 'Can this have taken place?' In some instances the effort to answer this question has led to a disbelief in miracles, in others to a strengthening of belief. The aim of Mr. Mozley's lectures is to show that the strengthening of belief is the logical result which ought to follow from the examination of the facts.

Attempts have been made by religious men to bring the Scripture miracles within the scope of the order of nature, but all such attempts are rejected by Mr. Mozley as utterly futile and wide of the mark. Regarding miracles as a necessary accompaniment of a revelation, their evidential value in his eyes depends entirely upon their deviation from the order of nature. Thus deviating, they suggest and illustrate a power higher than nature, a 'personal will;' and they commend the person in whom this power is vested as a messenger from on high. Without these credentials such a messenger would have no right to demand belief, even were his assertions regarding his Divine mission backed by a holy life. Nor is it by miracles alone that the order of nature is, or may be, disturbed. The material universe is also the arena of 'special providences.' Under these two heads Mr. Mozley distributes the total preternatural. One form of the preternatural may shade into the other, as one colour passes into another in the rainbow; but, while the line which divides the specially providential from the miraculous cannot be sharply drawn, their distinction broadly expressed is this: that, while a special providence can only excite surmise more or less probable, it is 'the nature of a miracle to give proof, as distinguished from mere surmise, of Divine design.'

Mr. Mozley adduces various illustrations of what he regards to be special providences, as distinguished from miracles. 'The death of Arius,' he says, 'was not miraculous, because the coincidence of the death of a heresiarch taking place when it was peculiarly advantageous to the orthodox faith . . . . was not such as to compel the inference of extraordinary Divine agency; but it was a special providence, because it carried a reasonable appearance of it. The miracle of the Thundering Legion was a special providence, but not a miracle, for the same reason, because the coincidence of an instantaneous fall of rain, in answer to prayer, carried some appearance, but not proof, of preternatural agency.' The eminent lecturer's remarks on this head brought to my recollection certain narratives published in Methodist magazines, which I used to read with avidity when a boy. The general title of these exciting stories, if I remember right, was 'The Providence of God asserted,' and in them the most extraordinary escapes from peril were recounted and ascribed to prayer, while equally wonderful instances of calamity were adduced as illustrations of Divine retribution. In such magazines, or elsewhere, I found recorded the case of the celebrated Samuel Hick, which, as it illustrates a whole class of special providences approaching in conclusiveness to miracles, is worthy of mention here. It is related of this holy man that, on one occasion, flour was lacking to make the sacramental bread. Grain was present, and a windmill was present, but there was no wind to grind the corn. With faith undoubting, Samuel Hick prayed to the Lord of the winds: the sails turned, the corn was ground, after which the wind ceased. According to the canon of the Bampton Lecturer, this, though carrying a strong appearance of an immediate exertion of Divine energy, lacks by a hair's-breadth the quality of a miracle. For the wind *might* have arisen, and *might* have ceased, in the ordinary course of nature. Hence the occurrence did not 'compel the inference of extraordinary Divine agency.' In like manner Mr. Mozley considers that 'the appearance of the cross to Constantine was a miracle, or a special providence, according to what account of it we adopt. As only a meteoric appearance in the shape of a cross it gave some token of preternatural agency, but not full evidence.'

In the Catholic canton of Switzerland where I now write, and still more among the pious Tyrolese, the mountains are dotted with shrines, containing offerings of all kinds, in acknowledgment of special mercies—legs, feet, arms, and hands—of gold, silver, brass, and wood, according as worldly possessions enabled the grateful heart to express its indebtedness. Most of these offerings are made to the Virgin Mary. They are recognitions of 'special providences,' wrought through the instrumentality of the Mother of God. Mr. Mozley's belief, that of the Methodist chronicler, and that of the Tyrolese peasant, are substantially the same. Each of them assumes that nature, instead of flowing ever onward in the uninterrupted rhythm of cause and effect, is mediately ruled by the free human will. As regards *direct* action upon natural phenomena, man's wish and will, as expressed in prayer, are confessedly powerless; but prayer is the trigger which liberates the Divine power, and to this extent, if the will be free, man, of course, commands nature.

Did the existence of this belief depend solely upon the material benefits derived from it, it could not, in my opinion, last a decade. As a purely objective fact, we should soon see that the distribution of natural phenomena is unaffected by the merits or the demerits of men; that the law of gravitation crushes the simple worshippers of Ottery St. Mary, while singing their hymns, just as surely as if they were engaged in a midnight brawl. The hold of this belief upon the human mind is not due to outward verification, but to the inner warmth, force, and elevation with which it is commonly associated. It is plain, however, that these feelings may exist under the most various forms. They are not limited to Church of England Protestantism—they are not even limited to Christianity. Though less refined, they are certainly not less strong in the heart of the Methodist and the Tyrolese peasant than in the heart of Mr. Mozley. Indeed, those feelings belong to the primal powers of man's nature. A 'sceptic' may have them. They find vent in the battle-cry of the Moslem. They take hue and form in the hunting-grounds of the Red Indian; and raise all of them, as they raise the Christian, upon a wave of victory, above the terrors of the grave.

The character, then, of a miracle, as distinguished from a special providence, is that the former furnishes *proof*, while in the case of the latter we have only surmise. Dissolve the element of doubt, and the alleged fact passes from the one class of the preternatural into the other. In other words, if a special providence could be proved to be a special providence, it would cease to be a special providence and become a miracle. There is not the least cloudiness about Mr. Mozley's meaning here. A special providence is a doubtful miracle. Why, then, not call it so? The term employed by Mr. Mozley conveys no negative suggestion, whereas the negation of certainty is the peculiar characteristic of the thing intended to be expressed. There is an apparent unwillingness on the part of the lecturer to call a special providence what his own definition makes it to be. Instead of speaking of it as a doubtful miracle, he calls it 'an invisible miracle.' He speaks of the point of contact of supernatural power with the chain of causation being so high up as to be wholly, or in part, out of sight, whereas the essence of a special providence is the uncertainty whether there is any contact at all, either high or low. By the use of an incorrect term, however, a grave danger is avoided. For the idea of doubt, if kept systematically before the mind, would soon be fatal to the special providence, considered as a means of edification. The term employed, on the contrary, invites and encourages the trust which is necessary to supplement the evidence.

This inner trust, though at first rejected by Mr. Mozley in favour of external proof, is subsequently called upon to do momentous duty in regard to miracles. Whenever the evidence of the miraculous seems incommensurate with the fact which it has to establish, or rather when the fact is so amazing that hardly any evidence is sufficient to establish it, Mr. Mozley invokes 'the affections.' They must urge the reason to accept the conclusion, from which unaided it recoils. The affections and emotions are eminently the court of appeal in matters of real religion, which is an affair of the heart; but they are not, I submit, the court in which to weigh allegations regarding the credibility of physical facts. These must be judged by the dry light of the intellect alone, appeals to the affections being reserved for cases where moral elevation, and not historic conviction, is the aim. It is, moreover, because the result, in the case under consideration, is deemed desirable that the affections are called upon to back it. If undesirable, they would, with equal right, be called upon to act the other way. Even to the disciplined scientific mind this would be a dangerous doctrine. A favourite theory—the desire to establish or avoid a certain result—can so warp the mind as to destroy its powers of estimating facts. I have known men to work for years under a fascination of this kind, unable to extricate themselves from its fatal influence. They had certain data, but not, as it happened, enough. By a process exactly analogous to that invoked by Mr. Mozley, they supplemented the data, and went wrong. From that hour their intellects were so blinded to the perception of adverse phenomena that they never reached truth. If, then, to the disciplined scientific mind, this incongruous mixture of proof and trust be fraught with danger, what must it be to the indiscriminate audience which Mr. Mozley addresses? In calling upon this agency he acts the part of Frankenstein. It is a monster thus evoked that we see stalking abroad, in the degrading spiritualistic phenomena of the present day. Again, I say, where the aim is to elevate the mind, to quicken the moral sense, to kindle the fire of religion in the soul, let the affections by all means be invoked; but they must not be permitted to colour our reports, or to influence our acceptance of reports of occurrences in external nature. Testimony as to natural facts is worthless when wrapped in this atmosphere of the affections; the most earnest subjective truth being thus rendered perfectly compatible with the most astounding objective error.

There are questions in judging of which the affections or sympathies are often our best guides, the estimation of moral goodness being one of these. But at this precise point, where they are really of use, Mr. Mozley excludes the affections and demands a miracle as a certificate of character. He will not accept any other evidence of the perfect goodness of Christ. 'No outward life and conduct,' he says, 'however irreproachable, could prove His perfect sinlessness, because goodness depends upon the inward motive, and the perfection of the inward motive is not proved by the outward act.' But surely the miracle is an outward act, and to pass from it to the inner motive imposes a greater strain upon logic than that involved in our ordinary methods of estimating men. There is, at least, moral congruity between the outward goodness and the inner life, but there is no such congruity between the miracle and the life within. The test of moral goodness laid down by Mr. Mozley is not the test of John, who says, 'He that doeth righteousness is righteous;' nor is it the test of Jesus: 'By their fruits ye shall know them: do men gather grapes of thorns, or figs of thistles?' But it *is* the test of another: 'If thou be the Son of God, command that these stones be made bread.' For my own part, I prefer the attitude of Fichte to that of Mr. Mozley. 'The Jesus of John,' says this noble and mighty thinker, 'knows no other God than the True God, in whom we all are, and live, and may be blessed, and out of whom there is only Death and Nothingness. And,' continues Fichte, 'he appeals, and rightly appeals, in support of this truth, not to reasoning, but to the inward practical sense of truth in man, not even knowing any other proof than this inward testimony, "If any man will do the will of Him who sent Me, he shall know of the doctrine whether it be of God."'

Accepting Mr. Mozley's test, with which alone I am now dealing, it is evident that, in the demonstration of moral goodness, the *quantity* of the miraculous comes into play. Had Christ, for example, limited himself to the conversion of water into wine, He would have fallen short of the performance of Jannes and Jambres; for it is a smaller thing to convert one liquid into another than to convert a dead rod into a living serpent. But Jannes and Jambres, we are informed, were not good. Hence, if Mr. Mozley's test be a true one, a point must exist, on the one side of which miraculous power demonstrates goodness, while on the other side it does not. How is this 'point of contrary flexure' to be determined? It must lie somewhere between the magicians and Moses, for within this space the power passed from the diabolical to the Divine. But how to mark the point of passage—how, out of a purely *quantitative* difference in the visible manifestation of power, we are to infer a total inversion of quality—it is extremely difficult to see. Moses, we are informed, produced a large reptile; Jannes and Jambres produced a small one. I do not possess the intellectual faculty which would enable me to infer, from those data, either the goodness of the one or the badness of the other; and in the highest recorded manifestations of the miraculous I am equally at a loss. Let us not play fast and loose with the miraculous; either it is a demonstration of goodness in all cases or in none. If Mr. Mozley accepts Christ's goodness as transcendent, because He did such works as no other man did, he ought, logically speaking, to accept the works of those who, in His name, had cast out devils, as demonstrating a proportionate goodness on their part. But it is people of this class who are consigned to everlasting fire prepared for the devil and his angels. Such zeal as that of Mr. Mozley for miracles tends, I fear, to eat his religion up. The logical threatens to stifle the spiritual. The truly religious soul needs no miraculous proof of the goodness of Christ. The words addressed to Matthew at the receipt of custom required no miracle to produce obedience. It was by no stroke of the supernatural that Jesus caused those sent to seize Him to go backward and fall to the ground. It was the sublime and holy effluence from within, which needed no prodigy to commend it to the reverence even of his foes.

As regards the function of miracles in the founding of a religion, Mr. Mozley institutes a comparison between the religion of Christ and that of Mahomet; and he derides the latter as 'irrational' because it does not profess to adduce miracles in proof of its supernatural origin. But the religion of Mahomet, notwithstanding this drawback, has thriven in the world, and at one time it held sway over larger populations than Christianity itself. The spread and influence of Christianity are, however, brought forward by Mr. Mozley as 'a permanent, enormous, and incalculable practical result' of Christian miracles; and he makes use of this result to strengthen his plea for the miraculous. His logical warrant for this proceeding is not clear. It is the method of science, when a phenomenon presents itself, towards the production of which several elements may contribute, to exclude them one by one, so as to arrive at length at the truly effective cause. Heat, for example, is associated with a phenomenon; we exclude heat, but the phenomenon remains: hence, heat is not its cause. Magnetism is associated with a phenomenon, we exclude magnetism, but the phenomenon remains: hence, magnetism is not its cause. Thus, also, when we seek the cause of a diffusion of a religion—whether it be due to miracles, or to the spiritual force of its founders—we exclude the miracles, and, finding the result unchanged, we infer that miracles are not the effective cause. This important experiment Mahometanism has made for us. It has lived and spread without miracles; and to assert, in the face of this, that Christianity has spread *because* of miracles, is, I submit, opposed both to the spirit of science and the common sense of mankind.

The incongruity of inferring moral goodness from miraculous power has been dwelt upon above; in another particular also the strain put by Mr. Mozley upon miracles is, I think, more than they can bear. In consistency with his principles, it is difficult to see how he is to draw from the miracles of Christ any certain conclusion as to His Divine nature. He dwells very forcibly on what he calls 'the argument from experience,' in the demolition of which he takes obvious delight. He destroys the argument, and repeats it, for the mere pleasure of again and again knocking the breath out of it. Experience, he urges, can only deal with the past; and the moment we attempt to project experience a hair's-breadth beyond the point it has at any moment reached, we are condemned by reason. It appears to me that when he infers from Christ's miracles a Divine and altogether superhuman energy, Mr. Mozley places himself precisely under this condemnation. For what is his logical ground for concluding that the miracles of the New Testament illustrate Divine power? May they not be the result of expanded human power? A miracle he defines as something impossible to man. But how does he know that the miracles of the New Testament are impossible to man? Seek as he may, he has absolutely no reason to adduce save this—that man has never hitherto accomplished such things. But does the fact that man *has* never raised the dead prove that he *can* never raise the dead? 'Assuredly not,' must be Mr. Mozley's reply; 'for this would be pushing experience beyond the limit it has now reached—which I pronounce unlawful.' Then a period may come when man will be able to raise the dead. If this be conceded —and I do not see how Mr. Mozley can avoid the concession—it destroys the necessity of inferring Christ's Divinity from His miracles. He, it may be contended, antedated the humanity of the future; as a mighty tidal wave leaves high upon the beach a mark which by-and-by becomes the general level of the ocean. Turn the matter as you will, no other warrant will be found for the all-important conclusion that Christ's miracles demonstrate Divine power, than an argument which has been stigmatised by Mr. Mozley as a 'rope of sand'—the argument from experience.

The learned Bampton Lecturer would be in this position, even had he seen with his own eyes every miracle recorded in the New Testament. But he has *not* seen these miracles; and his intellectual plight is therefore worse. He accepts these miracles on testimony. Why does he believe that testimony? How does he know that it is not delusion; how is he sure that it is not even fraud? He will answer, that the writing bears the marks of sobriety and truth; and that in many cases the bearers of this message to mankind sealed it with their blood. Granted with all my heart; but whence the value of all this? Is it not solely derived from the fact that men, *as we know them,* do not sacrifice their lives in the attestation of that which they know to be untrue? Does not the entire value of the testimony of the Apostles depend ultimately upon our experience of human nature? It appears, then, that those said to have seen the miracles, based their inferences from what they saw on the argument from experience; and that Mr. Mozley bases his belief in their testimony on the same argument. The weakness of his conclusion is quadrupled by this double insertion of a principle of belief, to which he flatly denies rationality. His reasoning, in fact, cuts two ways—if it destroys our trust in the order of nature, it far more effectually abolishes the basis on which Mr. Mozley seeks to found the Christian religion.

Over this argument from experience, which at bottom is *his* argument, Mr. Mozley rides rough-shod. There is a dash of scorn in the energy with which he tramples on it. Probably some previous writer had made too much of it, and thus invited his powerful assault. Finding the difficulty of belief in miracles to rise from their being in contradiction to the order of nature, he sets himself to examine the grounds of our belief in that order. With a vigour of logic rarely equalled, and with a confidence in its conclusions never surpassed, he disposes of this belief in a manner calculated to startle those who, without due examination, had come to the conclusion that the order of nature was secure.

What we mean, he says, by our belief in the order of nature, is the belief that the future will be like the past. There is not, according to Mr. Mozley, the slightest rational basis for this belief.

> 'That any cause in nature is more permanent than its existing and known effects, extending further, and about to produce other and more instances besides what it has produced already, we have no evidence. Let us imagine,' he continues, 'the occurrence of a particular physical phenomenon for the first time. Upon that single occurrence we should have but the very faintest expectation of another. If it did occur again, once or twice, so far from counting on another occurrence, a cessation would occur as the most natural event to us. But let it continue one hundred times, and we should find no hesitation in inviting persons from a distance to see it; and if it occurred every day for years, its occurrence would be a certainty to us, its cessation a

marvel. . . What ground of reason can we assign for an expectation that any part of the course of nature will be the next moment what it has been up to this moment, *i.e.* for our belief in the uniformity of nature? None. No demonstrative reason can be given, for the contrary to the recurrence of a fact of nature is no contradiction. No probable reason can be given; for all probable reasoning respecting the course of nature is founded *upon* this presumption of likeness, and therefore cannot be the foundation of it. No reason can be given for this belief. It is without a reason. It rests upon no rational grounds, and can be traced to no rational principle.'

'Everything,' Mr. Mozley, however, adds, 'depends upon this belief, every provision we make for the future, every safeguard and caution we employ against it, all calculation, all adjustment of means to ends, supposes this belief; and yet this belief has no more producible reason for it than a speculation of fancy. . . . . It is necessary, all-important for the purposes of life, but solely practical, and possesses no intellectual character. . . . . The proper function,' continues Mr. Mozley, 'of the inductive principle, the argument from experience, the belief in the order of nature—by whatever phrase we designate the same instinct—is to operate as a practical basis for the affairs of life and the carrying on of human society.' To sum up, the belief in the order of nature is general, but it is 'an unintelligent impulse, of which we can give no rational account.' It is inserted into our constitution solely to induce us to till our fields, to raise our winter fuel, and thus to meet the future on the perfectly gratuitous supposition that it will be like the past.

'Thus, step by step,' says Mr. Mozley, with the emphasis of a man who feels his position to be a strong one, 'has philosophy loosened the connection of the order of nature with the ground of reason, befriending in exact proportion as it has done this the principle of miracles.' For 'this belief not having itself a foundation in reason, the ground is gone upon which it could be maintained that miracles, as opposed to the order of nature, are opposed to reason.' When we regard this belief in connection with science, 'in which connection it receives a more imposing name, and is called the inductive principle,' the result is the same. 'The inductive principle is only this unreasoning impulse applied to a scientifically ascertained fact. . . . . Science has led up to the fact; but there it stops, and for converting this fact into a law, a totally unscientific principle comes into play, the same as that which generalises the commonest observation of nature.'

The eloquent pleader of the cause of miracles passes over without a word the *results* of scientific investigation, as proving anything rational regarding the principles or method by which such results have been achieved. Here, as elsewhere, he declines the test, 'By their fruits shall ye know them.' Perhaps our best way of proceeding will be to give one or two examples of the mode in which men of science apply the unintelligent impulse with which Mr. Mozley credits them, and which shall show, by illustration, the surreptitious method whereby they climb from the region of facts to that of laws.

Before the sixteenth century it was known that water rises in a pump; the effect being then explained by the maxim that 'Nature abhors a vacuum.' It was not known that there was any limit to the height to which the water would ascend, until, on one occasion, the gardeners of Florence, while attempting to raise water to a very great elevation, found that the column ceased at a height of thirty-two feet. Beyond this all the skill of the pump-maker could not get it to rise. The fact was brought to the notice of Galileo, and he, soured by a world which had not treated his science over kindly, is said to have twitted the philosophy of the time by remarking that nature evidently abhorred a vacuum only to a height of thirty-two feet. Galileo, however, did not solve the problem. It was taken up by his pupil Torricelli, to whom, after due pondering, the thought occurred, that the water might be forced into the tube by a pressure applied to the surface of the liquid outside. But where, under the actual circumstances, was such a pressure to be found? After much reflection, it flashed upon Torricelli that the atmosphere might possibly exert this pressure; that the impalpable air might possess weight, and that a column of water thirty-two feet high might be of the exact weight necessary to hold the pressure of the atmosphere in equilibrium.

There is much in this process of pondering and its results which it is impossible to analyse. It is by a kind of inspiration that we rise from the wise and sedulous contemplation of facts to the principles on which they depend. The mind is, as it were, a photographic plate, which is gradually cleansed by the effort to think rightly, and which, when so cleansed, and not before, receives impressions from the light of truth. This passage from facts to principles is called induction; and induction, in its highest form, is, as I have just stated, a kind of inspiration. But, to make it sure, the inward sight must be shown to be in accordance with outward fact. To prove or disprove the induction, we must resort to deduction and experiment.

Torricelli reasoned thus: If a column of water thirty-two feet high holds the pressure of the atmosphere in equilibrium, a shorter column of a heavier liquid ought to do the same. Now, mercury is thirteen times heavier than water; hence, if my induction be correct, the atmosphere ought to be able to sustain only thirty inches of mercury. Here, then, is a deduction which can be immediately submitted to experiment. Torricelli took a glass tube a yard or so in length, closed at one end and open at the other, and filling it with mercury, he stopped the open end with his thumb, and inverted it into a basin filled with the liquid metal. One can imagine the feeling with which Torricelli removed his thumb, and the delight he experienced on finding that his thought had forestalled a fact never before revealed to human eyes. The column sank, but it ceased to sink at a height of thirty inches, leaving the Torricellian vacuum over-head. From that hour the theory of the pump was established.

The celebrated Pascal followed Torricelli with another deduction. He reasoned thus: If the mercurial column be supported by the atmosphere, the higher we ascend in the air, the lower the column ought to sink, for the less will be the weight of the air overhead. He caused a friend to ascend the Puy de Dôme, carrying with him a barometric column; and it was found that during the ascent the column sank, and that during the subsequent descent the column rose.

Between the time here referred to and the present, millions of experiments have been made upon this subject. Every village pump is an apparatus for such experiments. In thousands of instances, moreover, pumps have refused to work; but on examination it has infallibly been found that the well was dry, that the pump required priming, or that some other defect in the apparatus accounted for the anomalous action. In every case of the kind the skill of the pump-maker has been found to be the true remedy. In no case has the pressure of the atmosphere ceased; constancy, as regards the lifting of pump-water, has been hitherto the demonstrated rule of nature. So also as regards Pascal's experiment. His experience has been the universal experience ever since. Men have climbed mountains, and gone up in balloons; but no deviation from Pascal's result has ever been observed. Barometers, like pumps, have refused to act; but instead of indicating any suspension of the operations of nature, or any interference on the part of its Author with atmospheric pressure, examination has in every instance fixed the anomaly upon the instruments themselves. It is this welding, then, of rigid logic to verifying fact that Mr. Mozley refers to an 'unreasoning impulse.'

Let us now briefly consider the case of Newton. Before his time men had occupied themselves with the problem of the solar system. Kepler had deduced, from a vast mass of observations, those general expressions of planetary motion known as 'Kepler's laws.' It had been observed that a magnet attracts iron; and by one of those flashes of inspiration which reveal to the human mind the vast in the minute, the general in the particular, it had been inferred, that the force by which bodies fall to the earth might also be an attraction. Newton pondered all these things. He looked, as was his wont, into the darkness until it became entirely luminous. How this light arises we cannot explain; but, as a matter of fact, it does arise. Let me remark here, that this kind of pondering is a process with which the ancients could have been but imperfectly acquainted. They, for the most part, found the exercise of fantasy more pleasant than careful observation, and subsequent brooding over facts. Hence it is, that when those whose education has been derived from the ancients speak of 'the reason of man,' they are apt to omit from their conception of reason one of its most important factors.

Well, Newton slowly marshalled his thoughts, or rather they came to him while he 'intended his mind,' rising like a series of intellectual births out of chaos. He made this idea of attraction his own. But, to apply the idea to the solar system, it was necessary to know the magnitude of the attraction, and the law of its variation with the distance. His conceptions first of all passed from the action of the earth as a whole, to that of its constituent particles. And persistent thought brought more and more clearly out the final conclusion, that every particle of matter attracts every other particle with a force varying inversely as the square of the distance between the particles.

Here we have the flower and outcome of Newton's induction; and how to verify it, or to disprove it, was the next question. The first step of the philosopher in this direction was to prove, mathematically, that if this law of attraction be the true one; if the earth be constituted of particles which obey this law; then the action of a sphere equal to the earth in size on a body outside of it, is the same as that which would be exerted if the whole mass of the sphere were contracted to a point at its centre. Practically speaking, then, the centre of the earth is the point from which distances must be measured to bodies attracted by the earth.

From experiments executed before his time, Newton knew the amount of the earth's attraction at the earth's surface, or at a distance of 4,000 miles from its centre. His object now was to measure the attraction at a greater distance, and thus to determine the law of its diminution. But how was he to find a body at a sufficient distance? He had no balloon? and even if he had, he knew that any height to which he could attain would be too small to enable him to solve his problem. What did he do? He fixed his thoughts upon the moon;—a body 240,000 miles, or sixty times the earth's radius, from the earth's centre. He virtually weighed the moon, and found that weight to be $\frac{1}{3600}$th of what it would be at the earth's surface. This is exactly what his theory required. I will not dwell here upon the pause of Newton after his first calculations, or speak of his self-denial in withholding them because they did not quite agree with the observations then at his command. Newton's action in this matter is the normal action of the scientific mind. If it were otherwise—if scientific men were not accustomed to demand verification—if they were satisfied with the imperfect while the perfect is attainable, their science, instead of being, as it is, a fortress of adamant, would be a house of clay, ill-fitted to bear the buffetings of the theologic storms to which it is periodically exposed.

Thus we see that Newton, like Torricelli, first pondered his facts, illuminated them with persistent thought, and finally divined the character of the force of gravitation. But, having thus travelled inward to the principle, he reversed his steps, carried the principle outwards, and justified it by demonstrating its fitness to external nature.

And here, in passing, I would notice a point which is well worthy of attention. Kepler had deduced his laws from observation. As far back as those observations extended, the planetary motions had obeyed these laws; and neither Kepler nor Newton entertained a doubt as to their continuing to obey them. Year after year, as the ages rolled, they believed that those laws would continue to illustrate themselves in the heavens. But this was not sufficient. The scientific mind can find no repose in the mere registration of sequence in nature. The further question intrudes itself with resistless might, Whence comes the sequence? What is it that binds the consequent to its antecedent in nature? The truly scientific intellect never can attain rest until it reaches the *forces* by which the observed succession is produced. It was thus with Torricelli; it was thus with Newton; it is thus pre-eminently with the scientific man of to-day. In common with the most ignorant, he shares the belief that spring will succeed winter, that summer will succeed spring, that autumn will succeed summer, and that winter will succeed autumn. But he knows still further—and this knowledge is essential to his intellectual repose—that this succession, besides being permanent, is, under the circumstances, *necessary*; that the gravitating force exerted between the sun and a revolving sphere with an axis inclined to the plane of its orbit, must produce the observed succession of the seasons. Not until this relation between forces and phenomena has been established, is the law of reason rendered concentric with the law of nature; and not until this is effected does the mind of the scientific philosopher rest in peace.

The expectation of likeness, then, in the procession of phenomena, is not that on which the scientific mind founds its belief in the order of nature. If the force be *permanent* the phenomena are *necessary*, whether they resemble or do not resemble anything that has gone before. Hence, in judging of the order of nature, our enquiries eventually relate to the permanence of force. From Galileo to Newton, from Newton to our own time, eager eyes have been scanning the heavens, and clear heads have been pondering the phenomena of the solar system. The same eyes and minds have been also observing, experimenting, and reflecting on the action of gravity at the surface of the earth. Nothing has occurred to indicate that the operation of the law has for a moment been suspended; nothing has ever intimated that nature has been crossed by spontaneous action, or that a state of things at any time existed which could not be rigorously deduced from the preceding state.

Given the distribution of matter, and the forces in operation, in the time of Galileo, the competent mathematician of that day could predict what is now occurring in our own. We calculate eclipses in advance, and find our calculations true to the second. We determine the dates of those that have occurred in the early times of history, and find calculation and history in harmony. Anomalies and perturbations in the planets have been over and over again observed; but these, instead of demonstrating any inconstancy on the part of natural law, have invariably been reduced to consequences of that law. Instead of referring the perturbations of Uranus to any interference on the part of the Author of nature with the law of gravitation, the question which the astronomer proposed to himself was, 'How, in accordance with this law, can the perturbation be produced?' Guided by a principle, he was enabled to fix the point of space in which, if a mass of matter were placed, the observed perturbations would follow. We know the result. The practical astronomer turned his telescope towards the region which the intellect of the theoretic astronomer had already explored, and the planet now named Neptune was found in its predicted place. A very respectable outcome, it will be admitted, of an impulse which 'rests upon no rational grounds, and can be traced to no rational principle;' which possesses 'no intellectual character;' which 'philosophy' has uprooted from 'the ground of reason,' and fixed in that 'large irrational department' discovered for it, by Mr. Mozley, in the hitherto unexplored wilderness of the human mind.

The proper function of the inductive principle, or the belief in the order of nature, says Mr. Mozley, is 'to act as a practical basis for the affairs of life, and the carrying on of human society.' But what, it may be asked, has the planet Neptune, or the belts of Jupiter, or the whiteness about the poles of Mars, to do with the affairs of society? How is society affected by the fact that the sun's atmosphere contains sodium, or that the nebula of Orion contains hydrogen gas? Nineteen-twentieths of the force employed in the exercise of the inductive principle, which, reiterates Mr. Mozley, is 'purely practical,' have been expended upon subjects as unpractical as these. What practical interest has society in the fact that the spots on the sun have a decennial period, and that when a magnet is closely watched for half a century, it is found to perform small motions which synchronise with the appearance and disappearance of the solar spots? And yet, I doubt not, Sir Edward Sabine would deem a life of intellectual toil amply rewarded by being privileged to solve, at its close, these infinitesimal motions.

The inductive principle is founded in man's desire to know—a desire arising from his position among phenomena which are reducible to order by his intellect. The material universe is the complement of the intellect; and, without the study of its laws, reason could never have awakened to the higher forms of self-consciousness at all. It is the Non-ego through and by which the Ego is endowed with self-discernment. We hold it to be an exercise of reason to explore the meaning of a universe to which we stand in this relation, and the work we have accomplished is the proper commentary on the methods we have pursued.

Before these methods were adopted the unbridled imagination roamed through nature, putting in the place of law the figments of superstitious dread. For thousands of years witchcraft, and magic, and miracles, and special providences, and Mr. Mozley's 'distinctive reason of man,' had the world to themselves. They made worse than nothing of it—*worse*, I say, because they let and hindered those who might have made something of it. Hence it is, that during a single lifetime of this era of 'unintelligent impulse,' the progress in knowledge is all but infinite as compared with that of the ages which preceded ours.

The believers in magic and miracles of a couple of centuries ago had all the strength of Mr. Mozley's present logic on their side. They had done for themselves what he rejoices in having so effectually done for us—cleared the ground of the belief in the order of nature, and declared magic, miracles, and witchcraft to be matters for 'ordinary evidence' to decide. 'The principle of miracles' thus 'befriended' had free scope, and we know the result. Lacking that rock-barrier of natural knowledge which we now possess, keen jurists and cultivated men were hurried on to deeds, the bare recital of which makes the blood run cold. Skilled in all the rules of human evidence, and versed in all the arts of cross-examination, these men, nevertheless, went systematically astray, and committed the deadliest wrongs against humanity. And why? Because they could not put Nature into the witness-box, and question her—of her voiceless 'testimony' they knew nothing. In all cases between man and man, their judgment was to be relied on; but in all cases between man and nature, they were blind leaders of the blind.[1]

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[1] 'In 1664 two women were hung in Suffolk, under a sentence of Sir Matthew Hale, who took the opportunity of declaring that

Mr. Mozley concedes that it would be no great result if miracles were only accepted by the ignorant and superstitious, 'because it is easy to satisfy those who do not enquire.' But he does consider it 'a great result' that they have been accepted by the educated. In what sense educated? Like those statesmen, jurists, and church dignitaries whose education was unable to save them from the frightful errors glanced at above? Not even in this sense; for the great mass of Mr. Mozley's educated people had no legal training, and must have been absolutely defenceless against delusions which could set even that training at naught. Like nine-tenths of our clergy at the present day, they were versed in the literature of Greece, Rome, and Judea; but as regards a knowledge of nature, which is here the one thing needful, they were 'noble savages,' and nothing more. In the case of miracles, then, it behoves us to understand the weight of the negative, before we assign a value to the positive; to comprehend the depositions of nature, before we attempt to measure, with them, the evidence of men. We have only to open our eyes to see what honest and even intellectual men and women are capable of, as to judging evidence, in this nineteenth century of the Christian era, and in latitude fifty-two degrees north. The experience thus gained ought, I imagine, to influence our opinion regarding the testimony of people inhabiting a sunnier clime, with a richer imagination, and without a particle

the reality of witchcraft was unquestionable; "for first, the Scriptures had affirmed so much; and secondly, the wisdom of all nations had provided laws against such persons, which is an argument of their confidence of such a crime." Sir Thomas Browne, who was a great physician as well as a great writer, was called as a witness, and swore "that he was clearly of opinion that the persons were bewitched."'—Lecky's *History of Rationalism*, vol. i. p. 120.

of that restraint which the discoveries of physical science have imposed upon mankind.

Having thus submitted Mr. Mozley's views to the examination which they challenged at the hands of a student of nature, I am unwilling to quit his book without expressing my admiration of his genius, and my respect for his character. Though barely known to him personally, his recent death affected me as that of a friend. With regard to the style of his book, I heartily subscribe to the description with which the 'Times' winds up its able and appreciative review. 'It is marked throughout with the most serious and earnest conviction, but is without a single word from first to last of asperity or insinuation against opponents; and this not from any deficiency of feeling as to the importance of the issue, but from a deliberate and resolutely maintained self-control, and from an over-ruling, ever-present sense of the duty, on themes like these, of a more than judicial calmness.'

[To the argument regarding the quantity of the miraculous, introduced at page 17, Mr. Mozley has done me the honour of publishing a Reply in the seventh volume of the 'Contemporary Review.'—J. T.]

ADDITIONAL REMARKS ON MIRACLES.

AMONG the scraps of manuscript, written at the time when Mr. Mozley's work occupied my attention, I find the following reflections:—

With regard to the influence of modern science which Mr. Mozley rates so low, one obvious effect of it is to enhance the magnitude of many of the recorded miracles, and to increase proportionably the difficulties of belief. The ancients knew but little of the vastness of the universe. The Rev. Mr. Kirkman, for example, has shown what inadequate notions the Jews entertained regarding the 'firmament of heaven;' and Sir George Airy refers to the case of a Greek philosopher who was persecuted for hazarding the assertion, then deemed monstrous, that the sun might be as large as the whole country of Greece. The concerns of a universe, regarded from this point of view, were much more commensurate with man and his concerns than those of the universe which science now reveals to us; and hence that to suit man's purposes, or that in compliance with his prayers, changes should occur in the order of the universe, was more easy of belief in the ancient world than it can be now. In the very magnitude which it assigns to natural phenomena, science has augmented the distance between them and man, and increased the popular belief in their orderly progression.

As a natural consequence the demand for evidence is more exacting than it used to be, whenever it is affirmed that the order of nature has been disturbed. Let us take as an illustration the miracle by which the victory of Joshua over the Amorites was rendered complete. In this case the sun is reported to have stood still for 'about a whole day' upon Gibeon, and the moon in the valley of Ajalon. An Englishman of average education at the present day would naturally demand a greater amount of evidence to prove that this occurrence took place, than would have satisfied an Israelite in the age succeeding that of Joshua. For to the one, the miracle probably consisted in the stoppage of a fiery ball less than a yard in diameter, while to the other it would be the stoppage of an orb fourteen hundred thousand times the earth in size. And even accepting the interpretation that Joshua dealt with what was apparent merely, but that what really occurred was the suspension of the earth's rotation, I think the right to exercise a greater reserve in accepting the miracle, and to demand stronger evidence in support of it than that which would have satisfied an ancient Israelite, will still be conceded to a man of science.

There is a scientific as well as an historic imagination; and when, by the exercise of the former, the stoppage of the earth's rotation is clearly realised, the event assumes proportions so vast, in comparison with the result to be obtained by it, that belief reels under the reflection. The energy here involved is equal to that of six trillions of horses working for the whole of the time employed by Joshua in the destruction of his foes. The amount of power thus expended would be sufficient to supply every individual of an army a thousand times the strength of that of Joshua, with a thousand times the fighting power of each of Joshua's soldiers, not for the few hours necessary to the extinction of a handful of Amorites, but for millions of years. All this wonder is silently passed over by the sacred historian, manifestly because he knew nothing about it. Whether, therefore, we consider the miracle as purely evidential, or as a practical means of vengeance, the same lavish squandering of energy stares us in the face. If evidential, the energy was wasted, because the Israelites knew nothing of its amount; if simply destructive, then the ratio of the quantity lost to the quantity employed, may be inferred from the foregoing figures.

To other miracles similar remarks apply. Transferring our thoughts from this little sand-grain of an earth to the immeasurable heavens, where countless worlds with freights of life probably revolve unseen, the very suns which warm them being barely visible across abysmal space; reflecting that beyond these sparks of solar fire, suns innumerable may burn, whose light can never stir the optic nerve at all; and bringing these reflections face to face with the idea of the Builder and Sustainer of it all showing Himself in a burning bush, exhibiting His hinder parts, or behaving in other familiar ways ascribed to Him in the Jewish Scriptures, the incongruity must appear. Did this credulous prattle of the ancients about miracles stand alone; were it not associated with words of imperishable wisdom, and with examples of moral grandeur unmatched elsewhere in the history of the human race, both the miracles and their 'evidences' would have long since ceased to be the transmitted inheritance of intelligent men. Influenced by the thoughts which this universe inspires, well may we exclaim in David's spirit, if not in David's words: 'When I consider the heavens, the work of thy fingers, the moon, and the stars, which thou hast ordained; what is man that thou shouldst be mindful of him, or the son of man that thou shouldst so regard him?'

If you ask me who is to limit the outgoings of Almighty power, my answer is, Not I. If you should urge that if the Builder and Maker of this universe chose to stop the rotation of the earth, or to take the form of a burning bush, there is nothing to prevent Him from doing so, I am not prepared to contradict you. I neither agree with you nor differ from you, for it is a subject of which I know nothing. But I observe that in such questions regarding Almighty power, your enquiries relate, not to that power as it is actually displayed in the universe, but to the power of your own imagination. Your question is, not has the Omnipotent done so and so? or is it in the least degree likely that the Omnipotent should do so and so? but, is my imagination competent to picture a Being able and willing to do so and so? I am not prepared to deny your competence. To the human mind belongs the faculty of enlarging and diminishing, of distorting and combining, indefinitely the objects revealed by the senses. It can imagine a mouse as large as an elephant, an elephant as large as a mountain, and a mountain as high as the stars. It can separate congruities and unite incongruities. We see a fish and we see a woman; we can drop one half of each, and unite in idea the other two halves to a mermaid. We see a horse and we see a man; we are able to drop one half of each, and unite the other two halves to a centaur. Thus also the pictorial representations of the Deity, the bodies and wings of cherubs and seraphs, the hoofs, horns, and tail of the Evil One, the joys of the blessed, and the torments of the damned, have been elaborated from materials furnished to the imagination by the senses. It behoves you and me to take care that our notions of the Power which rules the universe are not mere fanciful or ignorant enlargements of human power. The capabilities of what you call your reason are not denied. By the exercise of the faculty here adverted to, you can picture to yourself a Being able and willing to do any and every conceivable thing. You are right in saying that in opposition to this Power science is of no avail—that it is 'a weapon of air.' The man of science, however, while accepting the figure, would probably reverse its application, thinking it is not science which is here the thing of air, but that unsubstantial pageant of the imagination to which the solidity of science is opposed.

Prayer as a means to effect a private end is theft and meanness.—EMERSON.

III.

ON PRAYER AS A FORM OF PHYSICAL ENERGY.

THE Editor of the 'Contemporary Review' is liberal enough to grant me space for some remarks upon a subject, which, though my relation to it was simply that of a vehicle of transmission, has brought down upon me a considerable amount of animadversion.

It may be interesting to some of my readers if I glance at a few cases illustrative of the history of the human mind, in relation to this and kindred questions. In the fourth century the belief in Antipodes was deemed unscriptural and heretical. The pious Lactantius was as angry with the people who held this notion as my censors are now with me, and quite as unsparing in his denunciations of their 'Monstrosities.' Lactantius was irritated because, in his mind, by education and habit, cosmogony and religion were indissolubly associated, and, therefore, simultaneously disturbed. In the early part of the seventeenth century the notion that the earth was fixed, and that the sun and stars revolved round it daily, was interwoven with religious feeling, the separation then attempted by Galileo rousing the animosity and kindling the persecution of the Church. Men still living can remember the indignation excited by the first revelations of geology regarding the age of the earth, the association between chronology and religion being for the time indissoluble. In our day, however, the best-informed theologians are prepared to admit that our views of the Universe and its Author are not impaired, but improved, by the abandonment of the Mosaic account of the Creation. Look, finally, at the excitement caused by the publication of the 'Origin of Species;' and compare it with the calm attendant on the appearance of the far more outspoken, and, from the old point of view, more impious, 'Descent of Man.'

Thus religion survives after the removal of what had been long considered essential to it. In our day the Antipodes are accepted; the fixity of the earth is given up; the period of Creation and the reputed age of the world are alike dissipated; Evolution is looked upon without terror; and other changes have occurred in the same direction too numerous to be dwelt upon here. In fact, from the earliest times to the present, religion has been undergoing a process of purification, freeing itself slowly and painfully from the physical errors which the active but uninformed intellect mingled with the aspirations of the soul. Some of us think that a final act of purification is needed, while others oppose this notion with the confidence and the warmth of ancient times. The bone of contention at present is *the physical value of prayer*. It is not my wish to excite surprise, much less to draw forth protest, by the employment of this phrase. I would simply ask any intelligent person to look the problem honestly in the face, and then to say whether, in the estimation of the great body of those who sincerely resort to it, prayer does not, at all events upon special occasions, invoke a Power which checks and augments the descent of rain, which changes the force and direction of winds, which affects the growth of corn and the health of men and cattle—a Power, in short, which, when appealed to under pressing circumstances, produces the precise effects caused by physical energy in the ordinary course of things. To any person who deals sincerely with the subject, and refuses to blur his moral vision by intellectual subtleties, this, I think, will appear a true statement of the case.

It is under this aspect alone that the scientific student, so far as I represent him, has any wish to meddle with prayer. Forced upon his attention as a form of physical energy, or as the equivalent of such energy, he claims the right of subjecting it to those methods of examination from which all our present knowledge of the physical universe is derived. And if his researches lead him to a conclusion adverse to its claims—if his enquiries rivet him still closer to the philosophy implied in the words, 'He maketh His sun to shine on the evil and on the good, and sendeth rain upon the just and upon the unjust'—he contends only for the displacement of prayer, not for its extinction. He simply says, physical nature is not its legitimate domain.

This conclusion, moreover, must be based on pure physical evidence, and not on any inherent unreasonableness in the act of prayer. The theory that the system of nature is under the control of a Being who changes phenomena in compliance with the prayers of men, is, in my opinion, a perfectly legitimate one. It may of course be rendered futile by being associated with conceptions which contradict it; but such conceptions form no necessary part of the theory. It is a matter of experience that an earthly father, who is at the same time both wise and tender, listens to the requests of his children, and, if they do not ask amiss, takes pleasure in granting their requests. We know also that this compliance extends to the alteration, within certain limits, of the current of events on earth. With this suggestion offered by experience, it is no departure from scientific method to place behind natural phenomena a Universal Father, who, in answer to the prayers of His children, alters the currents of those phenomena. Thus far Theology and Science go hand in hand. The conception of an æther, for example, trembling with the waves of light, is suggested by the ordinary phenomena of wave-motion in water and in air; and in like manner the conception of personal volition in nature is suggested by the ordinary action of man upon earth. I therefore urge no *impossibilities*, though I am constantly charged with doing so. I do not even urge inconsistency, but, on the contrary, frankly admit that the theologian has as good a right to place his conception at the root of phenomena as I have to place mine.

But without *verification* a theoretic conception is a mere figment of the intellect, and I am sorry to find us parting company at this point. The region of theory, both in science and theology, lies behind the world of the senses, but the verification of theory occurs in the sensible world. To check the theory we have simply to compare the deductions from it with the facts of observation. If the deductions be in accordance with the facts, we accept the theory: if in opposition, the theory is given up. A single experiment is frequently devised, by which the theory must stand or fall. Of this character was the determination of the velocity of light in liquids, as a crucial test of the Emission Theory. According to it, light travelled faster in water than in air; according to the Undulatory Theory, it travelled faster in air than in water. An experiment suggested by Arago, and executed by Fizeau and Foucault, was conclusive against Newton's theory.

But while science cheerfully submits to this ordeal, it seems impossible to devise a mode of verification of their theories which does not rouse resentment in theological minds. Is it that, while the pleasure of the scientific man culminates in the demonstrated harmony between theory and fact, the highest pleasure of the religious man has been already tasted in the very act of praying, prior to verification, any further effort in this direction being a mere disturbance of his peace? Or is it that we have before us a residue of that mysticism of the middle ages, so admirably described by Whewell—that 'practice of referring things and events not to clear and distinct notions, not to general rules capable of direct verification, but to notions vague, distant, and vast, which we cannot bring into contact with facts; as when we connect natural events with moral and historic causes.' 'Thus,' he continues, 'the character of mysticism is that it refers particulars, not to generalisations, homogeneous and immediate, but to such as are heterogeneous and remote; to which we must add, that the process of this reference is not a calm act of the intellect, but is accompanied with a glow of enthusiastic feeling.'

Every feature here depicted, and some more questionable ones, have shown themselves of late; most conspicuously, I regret to say, in the 'leaders' of a weekly journal of considerable influence, and one, on many grounds, entitled to the respect of thoughtful men. In the correspondence, however, published by the same journal, are to be found two or three letters well calculated to correct the temporary flightiness of the journal itself.

It is not my habit of mind to think otherwise than solemnly of the feeling which prompts prayer. It is a power which I should like to see guided, not extinguished—devoted to practicable objects instead of wasted upon air. In some form or other, not yet evident, it may, as alleged, be necessary to man's highest culture. Certain it is that, while I rank many persons who resort to prayer low in the scale of being—natural foolishness, bigotry, and intolerance being in their case intensified by the notion that they have access to the ear of God—I regard others who employ it, as forming part of the very cream of the earth. The faith that adds to the folly and ferocity of the one is turned to enduring sweetness, holiness, abounding charity, and self-sacrifice by the other. Religion, in fact, varies with the nature upon which it falls. Often unreasonable, if not contemptible, prayer, in its purer forms, hints at disciplines which few of us can neglect without moral loss. But no good can come of giving it a delusive value, by claiming for it a power in physical nature. It may strengthen the heart to meet life's losses, and thus indirectly promote physical well-being, as the digging of Æsop's orchard brought a treasure of fertility greater than the golden treasure sought. Such indirect issues we all admit; but it would be simply dishonest to affirm that it is such issues that are always in view. Here, for the present, I must end. I ask no space to reply to those railers who make such free use of the terms insolence, outrage, profanity, and blasphemy. They obviously lack the sobriety of mind necessary to give accuracy to their statements, or to render their charges worthy of serious refutation.

IV.

VITALITY.

THE origin, growth, and energies of living things are subjects which have always engaged the attention of thinking men. To account for them it was usual to assume a special agent, free to a great extent from the limitations observed among the powers of inorganic nature. This agent was called *vital force*; and, under its influence, plants and animals were supposed to collect their materials and to assume determinate forms. Within the last few years, however, our ideas of vital processes have undergone profound modifications; and the interest, and even disquietude, which the change has excited are amply evidenced by the discussions and protests which are now common, regarding the phenomena of vitality. In tracing these phenomena through all their modifications, the most advanced philosophers of the present day declare that they ultimately arrive at a single source of power, from which all vital energy is derived; and the disquieting circumstance is that this source is not the direct fiat of a supernatural agent, but a reservoir of what, if we do not accept the creed of Zoroaster, must be regarded as *inorganic* force. In short, it is considered as proved that all the energy which we derive from plants and animals is drawn from the sun.

A few years ago, when the sun was affirmed to be the source of life, nine out of ten of those who are alarmed by the form which this assertion has latterly assumed would have assented, in a general way, to its correctness. Their assent, however, was more poetic than scientific, and they were by no means prepared to see a rigid mechanical signification attached to their words. This, however, is the peculiarity of modern conclusions:—that there is no creative energy whatever in the vegetable or animal organism, but that all the power which we obtain from the muscles of man and animals, as much as that which we develop by the combustion of wood or coal, has been produced at the sun's expense. The sun is so much the colder that we may have our fires; he is also so much the colder that we may have our horse-racing and Alpine climbing. It is, for example, certain that the sun has been chilled to an extent capable of being accurately expressed in numbers, in order to furnish the power which lifted this year a certain number of tourists from the vale of Chamouni to the summit of Mont Blanc.

To most minds, however, the energy of light and heat presents itself as a thing totally distinct from ordinary mechanical energy. Either of them can nevertheless be derived from the other. Wood can be raised by friction to the temperature of ignition; while by properly striking a piece of iron a skilful blacksmith can cause it to glow. Thus, by the rude agency of his hammer, he generates light and heat. This action, if carried far enough, would produce the light and heat of the sun. In fact, the sun's light and heat have actually been referred to the fall of meteoric matter upon his surface; and whether the sun is thus supported or not, it is perfectly certain that he *might be* thus supported. Whether, moreover, the whilom molten condition of our planet was, as supposed by eminent men, due to the collision of cosmic masses or not, it is perfectly certain that the molten condition *might be* thus brought about.

If, then, solar light and heat can be produced by the impact of dead matter, and if from the light and heat thus produced we can derive the energies which we have been accustomed to call *vital*, it indubitably follows that vital energy may have a proximately mechanical origin.

In what sense, then, is the sun to be regarded as the origin of the energy derivable from plants and animals? Let us try to give an intelligible answer to this question. Water may be raised from the sea-level to a high elevation, and then permitted to descend. In descending it may be made to assume various forms—to fall in cascades, to spurt in fountains, to boil in eddies, or to flow tranquilly along a uniform bed. It may, moreover, be caused to set complex machinery in motion, to turn millstones, throw shuttles, work saws and hammers, and drive piles. But every form of power here indicated would be derived from the original power expended in raising the water to the height from which it fell. There is no energy *generated* by the machinery: the work performed by the water in descending is merely the parcelling out and distribution of the work expended in raising it. In precisely this sense is all the energy of plants and animals the parcelling out and distribution of a power originally exerted by the sun. In the case of the water, the source of the power consists in the forcible separation of a quantity of the liquid from a low level of the earth's surface, and its elevation to a higher position, the power thus expended being returned by the water in its descent. In the case of vital phenomena, the source of power consists in the forcible separation of the atoms of compound substances by the sun. We name the force which draws the water earthward 'gravity,' and that which draws atoms together 'chemical affinity'; but these different names must not mislead us regarding the qualitative identity of the two forces. They are both *attractions*; and, to the intellect, the falling of carbon atoms against oxygen atoms is not more difficult of conception than the falling of water to the earth.

The building up of the vegetable, then, is effected by the sun, through the reduction of chemical compounds. The phenomena of animal life are more or less complicated reversals of these processes of reduction. We eat the vegetable, and we breathe the oxygen of the air; and in our bodies the oxygen, which had been lifted from the carbon and hydrogen by the action of the sun, again falls towards them, producing animal heat and developing animal forms. Through the most complicated phenomena of vitality this law runs:—the vegetable is produced while a weight rises, the animal is produced while a weight falls. But the question is not exhausted here. The water employed in our first illustration generates all the motion displayed in its descent, but the *form* of the motion depends on the character of the machinery interposed in the path of the water. In a similar way, the primary action of the sun's rays is qualified by the atoms and molecules among which their energy is distributed. Molecular forces determine the form which the solar energy will assume. In the separation of the carbon and oxygen this energy may be so conditioned as to result in one case in the formation of a cabbage, and in another case in the formation of an oak. So also, as regards the reunion of the carbon and the oxygen, the molecular machinery through which the combining energy acts may, in one case, weave the texture of a frog, while in another it may weave the texture of a man.

The matter of the animal body is that of inorganic nature. There is no substance in the animal tissues which is not primarily derived from the rocks, the water, and the air. Are the forces of organic matter, then, different in kind from those of inorganic matter? The philosophy of the present day negatives the question. It is the compounding, in the organic world, of forces belonging equally to the inorganic, that constitutes the mystery and the miracle of vitality. Every portion of every animal body may be reduced to purely inorganic matter. A perfect reversal of this process of reduction would carry us from the inorganic to the organic; and such a reversal is at least conceivable. The tendency, indeed, of modern science is to break down the wall of partition between organic and inorganic, and to reduce both to the operation of forces which are the same in kind, but which are differently compounded.

Consider the question of personal identity, in relation to that of molecular form. Thirty-four years ago, Mayer of Heilbronn, with that power of genius which breathes large meanings into scanty facts, pointed out that the blood was 'the oil of the lamp of life,' the combustion of which sustains muscular action. The muscles are the machinery by which the dynamic power of the blood is brought into play. Thus the blood is consumed. But the whole body, though more slowly than the blood, wastes also, so that after a certain number of years it is entirely renewed. How is the sense of personal identity maintained across this flight of molecules? To man, as we know him, matter is necessary to consciousness; but the matter of any period may be all changed, while consciousness exhibits no solution of continuity. Like changing sentinels, the oxygen, hydrogen, and carbon that depart, seem to whisper their secret to their comrades that arrive, and thus, while the Non-ego shifts, the Ego remains the same. Constancy of form in the grouping of the molecules, and not constancy of the molecules themselves, is the correlative of this constancy of perception. Life is a *wave* which in no two consecutive moments of its existence is composed of the same particles.

Supposing, then, the molecules of the human body, instead of replacing others, and thus renewing a pre-existing form, to be gathered first hand from nature and put together in the same relative positions as those which they occupy in the body. Supposing them to have the selfsame forces and distribution of forces, the selfsame motions and distribution of motions—would this organised concourse of molecules stand before us as a sentient thinking being? There seems no valid reason to believe that it would not. Or, supposing a planet carved from the sun, set spinning round an axis, and revolving round the sun at a distance from him equal to that of our earth, would one of the consequences of its refrigeration be the development of organic forms? I lean to the affirmative. *Structural* forces are certainly in the mass, whether or not those forces reach to the extent of forming a plant or an animal. In an amorphous drop of water lie latent all the marvels of crystalline force; and who will set limits to the possible play of molecules in a cooling planet? If these statements startle, it is because matter has been defined and maligned by philosophers and theologians, who were equally unaware that it is, at bottom, essentially mystical and transcendental.

Questions such as these derive their present interest in great part from their audacity, which is sure, in due time, to disappear. And the sooner the public dread is abolished with reference to such questions the better for the cause of truth. As regards knowledge, physical science is polar. In one sense it knows, or is destined to know, everything. In another sense it knows nothing. Science understands much of this intermediate phase of things that we call nature, of which it is the product; but science knows nothing of the origin or destiny of nature. Who or what made the sun, and gave his rays their alleged power? Who or what made and bestowed upon the ultimate particles of matter their wondrous power of varied interaction? Science does not know: the mystery, though pushed back, remains unaltered. To many of us who feel that there are more things in heaven and earth than are dreamt of in the present philosophy of science, but who have been also taught, by baffled efforts, how vain is the attempt to grapple with the Inscrutable, the ultimate frame of mind is that of Goethe:

Who dares to name His name,
Or belief in Him proclaim,
Veiled in mystery as He is, the All-enfolder?
Gleams across the mind His light,
Feels the lifted soul His might,
Dare it then deny His reign, the All-upholder?

As I rode through the Schwarzwald, I said to myself: That little fire which glows star-like across the dark-growing moor, where the sooty smith bends over his anvil, and thou hopest to replace thy lost horse-shoe,—is it a detached, separated speck, cut off from the whole Universe; or indissolubly joined to the whole? Thou fool, that smithy-fire was primarily kindled at the Sun; is fed by air that circulates from before Noah's Deluge, from beyond the Dogstar; therein, with Iron Force, and Coal Force, and the far stranger Force of Man, are cunning affinities and battles and victories of Force brought about; it is a little ganglion, or nervous centre, in the great vital system of Immensity. Call it, if thou wilt, an unconscious Altar, kindled on the bosom of the All . . . . Detached, separated! I say there is no such separation: nothing hitherto was ever stranded, cast aside; but all, were it only a withered leaf, works together with all; is borne forward on the bottomless, shoreless flood of action, and lives through perpetual metamorphoses.—CARLYLE.

V.

MATTER AND FORCE.[1]

IT is the custom of the Professors in the Royal School of Mines in London to give courses of evening lectures every year to working men. The lecture-room holds 600 people; and tickets to this amount are disposed of as quickly as they can be handed to those who apply for them. So desirous are the working men of London to attend these lectures, that the persons who fail to obtain tickets always bear a large proportion to those who succeed. Indeed, if the lecture-room could hold 2,000 instead of 600, I do not doubt that every one of its benches would be occupied on these occasions. It is, moreover, worthy of remark that the lectures are but rarely of a character which could help the working man in his daily pursuits. The information acquired is hardly ever of a nature which admits of being turned into money. It is, therefore, a pure desire for knowledge, as a thing good in itself, and without regard to its practical application, which animates the hearers of these lectures.

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[1] A Lecture delivered to the working men of Dundee, September 5, 1867, with additions.

It is also my privilege to lecture to another audience in London, composed in part of the aristocracy of rank, while the audience just referred to is composed wholly of the aristocracy of labour. As regards attention and courtesy to the lecturer, neither of these audiences has anything to learn of the other; neither can claim superiority over the other. It would not, perhaps, be quite correct to take those persons who flock to the School of Mines as average samples of their class; they are probably picked men—the aristocracy of labour, as I have just called them. At all events, their conduct demonstrates that the essential qualities of what we in England understand by a gentleman are confined to no class; and they have often raised in my mind the wish that the gentlemen of all classes, artisans as well as lords, could, by some process of selection, be sifted from the general mass of the community, and caused to know each other better.

When pressed some months ago by the Council of the British Association to give an evening lecture to the working men of Dundee, my experience of the working men of London naturally rose to my mind; and, though heavily weighted with other duties, I could not bring myself to decline the request of the Council. Hitherto, the evening discourses of the Association have been delivered before its members and associates alone. But after the meeting at Nottingham, last year, where the working men, at their own request, were addressed by our late President, Mr. Grove, and by my excellent friend, Professor Huxley, the idea arose of incorporating with all subsequent meetings of the Association an address to the working men of the town in which the meeting is held. A resolution to that effect was sent to the Committee of Recommendations; the Committee supported the resolution; the Council of the Association ratified the decision of the Committee; and here I am to carry out to the best of my ability their united wishes.

Whether it be a consequence of long-continued development, or an endowment conferred once for all on man at his creation, we find him here gifted with a mind curious to know the causes of things, and surrounded by objects which excite its questionings, and raise the desire for an explanation. It is related of a young Prince of one of the Pacific Islands, that when he first saw himself in a looking-glass, he ran round the glass to see who was standing at the back. And thus it is with the general human intellect, as regards the phenomena of the external world. It wishes to get behind and learn the causes and connections of these phenomena. What is the sun, what is the earth, what should we see if we came to the edge of the earth and looked over? What is the meaning of thunder and lightning, of hail, rain, storm, and snow? Such questions presented themselves to early men, and by and by it was discovered that this desire for knowledge was not implanted in vain. After many trials it became evident that man's capacities were, so to speak, the complement of nature's facts, and that, within certain limits, the secret of the universe was open to the human understanding. It was found that the mind of man had the power of penetrating far beyond the boundaries of his five senses; that the things which are seen in the material world depend for their action upon things unseen; in short, that besides the phenomena which address the senses, there are laws and principles and processes which do not address the senses at all, but which must be, and can be, spiritually discerned.

To the subjects which require this discernment belong the phenomena of molecular force. But to trace the genesis of the notions now entertained upon this subject, we have to go a long way back. In the drawing of a bow, the darting of a javelin, the throwing of a stone—in the lifting of burdens, and in personal combats, even savage man became acquainted with the operation of *force*. Ages of discipline, moreover, taught him foresight. He laid by at the proper season stores of food, thus obtaining time to look about him, and to become an observer and enquirer. Two things which he noticed must have profoundly stirred his curiosity. He found that a kind of resin dropped from a certain tree possessed, when rubbed, the power of drawing light bodies to itself, and of causing them to cling to it; and he also found that a particular stone exerted a similar power over a particular kind of metal. I allude, of course, to electrified amber, and to the loadstone, or natural magnet, and its power to attract particles of iron. Previous experience of his own muscles had enabled our early enquirer to distinguish between a push and a pull. Augmented experience showed him that in the case of the magnet and the amber, pulls and pushes—attractions and repulsions—were also exerted; and, by a kind of poetic transfer, he applied to things external to himself, conceptions derived from himself. The magnet and the rubbed amber were credited with pushing and pulling, or, in other words, with exerting force.

In the time of the great Lord Bacon the margin of these pushes and pulls was vastly extended by Dr. Gilbert, a man probably of firmer scientific fibre, and of finer insight, than Bacon himself. Gilbert proved that a multitude of other bodies, when rubbed, exerted the power which, thousands of years previously, had been observed in amber. In this way the notion of attraction and repulsion in external nature was rendered familiar. It was a matter of experience that bodies, between which no visible link or connection existed, possessed the power of acting upon each other; and the action came to be technically called 'action at a distance.'

But out of experience in science there grows something finer than mere experience. Experience furnishes the soil for plants of higher growth; and this observation of action at a distance provided material for speculation upon the largest of problems. Bodies were observed to fall to the earth. Why should they do so? The earth was proved to revolve round the sun; and the moon to revolve round the earth. Why should they do so? What prevents them from flying straight off into space? Supposing it were ascertained that from a part of the earth's rocky crust a firmly fixed and tightly stretched chain started towards the sun, we might be inclined to conclude that the earth is held in its orbit by the chain—that the sun twirls the earth around him, as a boy twirls round his head a bullet at the end of a string. But why should the chain be needed? It is a fact of experience that bodies can attract each other at a distance, without the intervention of any chain. Why should not the sun and earth so attract each other? and why should not the fall of bodies from a height be the result of their attraction by the earth? Here then we reach one of those higher speculations which grow out of the fruitful soil of observation. Having started with the savage, and his sensations of muscular force, we pass on to the observation of force exerted between a magnet and rubbed amber and the bodies which they attract, rising, by an unbroken growth of ideas, to a conception of the force by which sun and planets are held together.

This idea of attraction between sun and planets had become familiar in the time of Newton. He set himself to examine the attraction; and here, as elsewhere, we find the speculative mind falling back for its materials upon experience. It had been observed, in the case of magnetic and electric bodies, that the nearer they were brought together the stronger was the force exerted between them; while, by increasing the distance, the force diminished until it became insensible. Hence the inference that the assumed pull between the earth and the sun would be influenced by their distance asunder. Guesses had been made as to the exact manner in which the force varied with the distance; but Newton supplemented the guess by the severe test of experiment and calculation. Comparing the pull of the earth upon a body close to its surface, with its pull upon the moon, 240,000 miles away, Newton rigidly established the law of variation with the distance. But on his way to this result Newton found room for other conceptions, some of which, indeed, constituted the necessary stepping-stones to his result. The one which here concerns us is, that not only does the sun attract the earth, and the earth attract the sun, *as wholes*, but every particle of the sun attracts every particle of the earth, and the reverse. His conclusion was, that the attraction of the masses was simply the sum of the attractions of their constituent particles.

This result seems so obvious that you will perhaps wonder at my dwelling upon it; but it really marks a turning point in our notions of force. You have probably heard of certain philosophers of the ancient world named Democritus, Epicurus, and Lucretius. These men adopted, developed, and diffused the doctrine of atoms and molecules, which found its consummation at the hands of the illustrious John Dalton. But the Greek and Roman philosophers I have named, and their followers, up to the time of Newton, pictured their atoms as falling and flying through space, hitting each other, and clinging together by imaginary hooks and claws. They missed the central idea that atoms and molecules could come together, not by being fortuitously knocked against each other, but by their own mutual attractions. This is one of the great steps taken by Newton. He familiarised the world with the conception of *molecular force.*

Newton, you know, was preceded by a grand fellow named John Kepler—a true working man—who, by analysing the astronomical observations of his master, Tycho Brahe, had actually found that the planets moved as they are now known to move. Kepler knew as much about the motion of the planets as Newton did; in fact, Kepler taught Newton and the world generally the facts of planetary motion. But this was not enough. The question arose—Why should the facts be so? This was the great question for Newton, and it was the solution of it which renders his name and fame immortal. Starting from the principle that every particle of matter in the solar system attracts every other particle by a force which varies as the inverse square of the distance between the particles, he proved that the planetary motions must be what observation makes them to be. He showed that the moon fell towards the earth, and that the planets fell towards the sun, through the operation of the same force that pulls an apple from its tree. This all-pervading force, which forms the solder of the material universe, and the conception of which was necessary to Newton's intellectual peace, is called the force of gravitation.

Gravitation is a purely attractive force, but in electricity and magnetism, repulsion had been always seen to accompany attraction. Electricity and magnetism are double or *polar forces*. In the case of magnetism, experience soon pushed the mind beyond the bounds of experience, compelling it to conclude that the polarity of the magnet was resident in its molecules. I hold a magnetised strip of steel by its centre, and find that one half of the strip attracts, and the other half repels, the north end of a magnetic needle. I break the strip in the middle, find that this half, which a moment ago attracted throughout its entire length the north pole of a magnetic needle, is now divided into two new halves, one of which wholly attracts, and the other of which wholly repels, the north pole of the needle. The half proves to be as perfect a magnet as the whole. You may break this half and go on till further breaking becomes impossible through the very smallness of the fragments; the smallest fragment is found endowed with two poles, and is, therefore, a perfect magnet. But you cannot stop here: you *imagine* where you cannot *experiment*; and reach the conclusion entertained by all scientific men, that the magnet which you see and feel is an assemblage of molecular magnets which you cannot see and feel, but which, as before stated, must be intellectually discerned.

Magnetism then is a polar force; and experience hints that a force of this kind may exert a certain structural power. It is known, for example, that iron filings strewn round a magnet arrange themselves in definite lines, called, by some, 'magnetic curves,' and, by others, 'lines of magnetic force.' Over two magnets now before me is spread a sheet of paper. Scattering iron filings over the paper, polar force comes into play, and every particle of the iron responds to that force. We have a kind of architectural effort—if I may use the term—exerted on the part of the iron filings. Here then is a fact of experience which, as you will see immediately, furnishes further material for the mind to operate upon, rendering it possible to attain intellectual clearness and repose, while speculating upon apparently remote phenomena.

The magnetic force has here acted upon particles visible to the eye. But, as already stated, there are numerous processes in nature which entirely elude the eye of the body, and must be figured by the eye of the mind. The processes of chemistry are examples of these. Long thinking and experimenting has led philosophers to conclude that matter is composed of atoms from which, whether separate or in combination, the whole material world is built up. The air we breathe, for example, is mainly a mechanical mixture of the atoms of oxygen and nitrogen. The water we drink is also composed of oxygen and hydrogen. But it differs from the air in this particular, that in water the oxygen and hydrogen are not mechanically mixed, but chemically combined. The atoms of oxygen and those of hydrogen exert enormous attractions on each other, so that when brought into sufficient proximity they rush together with an almost incredible force to form a chemical compound. But powerful as is the force with which these atoms lock themselves together, we have the means of tearing them asunder, and the agent by which we accomplish this may here receive a few moments' attention.

Into a vessel containing acidulated water I dip two strips of metal, the one being zinc and the other platinum, not permitting them to touch each other in the liquid. I connect the two upper ends of the strips by a piece of copper wire. The wire is now the channel of what, for want of a better name, we call an 'electric current.' What the inner change of the wire is we do not know, but we do know that a change has occurred, by the external effects produced by the wire. Let me show you one or two of these effects. Before you is a series of ten vessels, each with its pair of metals, and I wish to get the added force of all ten. The arrangement is called a voltaic battery. I plunge a piece of copper wire among these iron filings; they refuse to cling to it. I employ the selfsame wire to connect the two ends of the battery, and subject it to the same test. The iron filings now crowd round the wire and cling to it. I interrupt the current, and the filings immediately fall; the power of attraction continues only so long as the wire connects the two ends of the battery.

Here is a piece of similar wire, overspun with cotton, to prevent the contact of its various parts, and formed into a coil. I make the coil part of the wire which connects the two ends of the voltaic battery. By the attractive force with which it has become suddenly endowed, it now empties this tool-box of its iron nails. I twist a covered copper wire round this common poker; connecting the wire with the two ends of the voltaic battery, the poker is instantly transformed into a strong magnet. Two flat spirals are here suspended facing each other, about six inches apart. Sending a current through both spirals, they clash suddenly together; reversing what is called the direction of the current in one of the spirals, they fly asunder. All these effects are due to the power which we name an electric current, and which we figure as flowing through the wire when the voltaic circuit is complete.

By the same agent we tear asunder the locked atoms of a chemical compound. Into this small cell, containing water, dip two thin wires. A magnified image of the cell is thrown upon the screen before you, and you see plainly the images of the wires. From a small battery I send an electric current from wire to wire. Bubbles of gas rise immediately from each of them, and these are the two gases of which the water is composed. The oxygen is always liberated on the one wire, the hydrogen on the other. The gases may be collected either separately or mixed. I place upon my hand a soap bubble filled with the mixture of both gases. Applying a taper to the bubble, a loud explosion is heard. The atoms have rushed together with detonation, and without injury to my hand, and the water from which they were extracted is the result of their re-union.

One consequence of the rushing together of the atoms is the development of heat. What is this heat? Here are two ivory balls suspended from the same point of support by two short strings. I draw them thus apart and then liberate them. They clash together, but, by virtue of their elasticity, they quickly recoil, and a sharp vibratory rattle succeeds their collision. This experiment will enable you to figure to your mind a pair of clashing atoms. We have in the first place, a motion of the one atom towards the other—a motion of translation, as it is usually called—then a recoil, and afterwards a motion of vibration. To this vibratory motion we give the name of heat. Thus, three things are to be kept before the mind—first, the atoms themselves; secondly, the force with which they attract each other; and thirdly, the motion consequent upon the exertion of that force. This motion must be figured first as a motion of translation, and then as a motion of vibration, to which latter we give the name of heat. For some time after the act of combination this motion is so violent as to prevent the molecules from coming together, the water being maintained in a state of vapour. But as the vapour cools, or in other words loses its motion, the molecules coalesce to form a liquid.

And now we approach a new and wonderful display of force. As long as the substance remains in a liquid or vaporous condition, the play of this force is altogether masked and hidden. But as the heat is gradually withdrawn, the molecules prepare for new arrangements and combinations. Solid crystals of water are at length formed, to which we give the familiar name of ice. Looking at these beautiful edifices and their internal structure, the pondering mind has forced upon it the question, How are they built up? We have obtained clear conceptions of polar force; and we infer from our broken magnet that polar force may be resident in the molecules or smallest particles of matter, and that by the play of this force structural arrangement is possible. What, in relation to our present question, is the natural action of a mind furnished with this knowledge? It is compelled to transcend experience, and endow the atoms and molecules of which crystals are built with definite poles whence issue attractions and repulsions. In virtue of these forces some poles are drawn together, while some retreat from each other; atom is added to atom, and molecule to molecule, not boisterously or fortuitously, but silently and symmetrically, and in accordance with laws more rigid than those which guide a human builder when he places his materials together. Imagine the bricks and stones of this town of Dundee endowed with structural power.

Imagine them attracting and repelling, and arranging themselves into streets and houses and Kinnaird Halls—would not that be wonderful? Hardly less wonderful is the play of force by which the molecules of water build themselves into the sheets of ice which every winter roof your ponds and lakes.

If I could show you the actual progress of this molecular architecture, its beauty would delight and astonish you. A reversal of the process of crystallisation may be actually shown. The molecules of a piece of ice may be taken asunder before your eyes; and from the manner in which they separate, you may to some extent infer the manner in which they go together. When a beam is sent from our electric lamp through a plate of glass, a portion of the beam is intercepted, and the glass is warmed by the portion thus retained within it. When the beam is sent through a plate of ice, a portion of the beam is also absorbed; but instead of warming the ice, the intercepted heat melts it internally. It is to the delicate silent action of this beam within the ice that I now wish to direct your attention. Upon the screen is thrown a magnified image of the slab of ice: the light of the beam passes freely through the ice without melting it, and enables us to form the image; but the heat is in great part intercepted, and that heat now applies itself to the work of internal liquefaction. Selecting certain points for attack, round about those points the beam works silently, undoing the crystalline architecture, and reducing to the freedom of liquidity molecules which had been previously locked in a solid embrace. The liquefied spaces are rendered visible by strong illumination. Observe those six-petaled flowers breaking out over the white surface, and expanding in size as the action of the beam continues. These flowers are liquefied ice. Under the action of the heat the molecules of the crystals fall asunder, so as to leave behind them these exquisite forms. We have here a process of demolition which clearly reveals the reverse process of construction. In this fashion, and in strict accordance with this hexangular type, every ice molecule takes its place upon our ponds and lakes during the frosts of winter. To use the language of an American poet, 'the atoms march in tune,' moving to the music of law, which thus renders the commonest substance in nature a miracle of beauty.

It is the function of science, not as some think to divest this universe of its wonder and mystery, but, as in the case before us, to point out the wonder and the mystery of common things. Those fern-like forms, which on a frosty morning overspread your window-panes, illustrate the action of the same force. Breathe upon such a pane before the fires are lighted, and reduce the solid crystalline film to the liquid condition; then watch its subsequent resolidification. You will see it all the better if you look at it through a common magnifying glass. After you have ceased breathing, the film, abandoned to the action of its own forces, appears for a moment to be alive. Lines of motion run through it; molecule closes with molecule, until finally the whole film passes from the state of liquidity, through this state of motion, to its final crystalline repose.

I can show you something similar. Over a piece of perfectly clean glass I pour a little water in which certain crystals have been dissolved. A film of the solution clings to the glass. By means of a microscope and a lamp, an image of the plate of glass is thrown upon the screen. The beam of the lamp, besides illuminating the glass, also heats it; evaporation sets in, and at a certain moment, when the solution has become supersaturated, splendid branches of crystal shoot out over the screen. A dozen square feet of surface are now covered by those beautiful forms. With another solution we obtain crystalline spears, feathered right and left by other spears. From distant nuclei in the middle of the field of view the spears shoot with magical rapidity in all directions. The film of water on a window-pane on a frosty morning exhibits effects quite as wonderful as these. Latent in these formless solutions, latent in every drop of water, lies this marvellous structural power, which only requires the withdrawal of opposing forces to bring it into action.

The clear liquid now held up before you is a solution of nitrate of silver—a compound of silver and nitric acid. When an electric current is sent through this liquid the silver is severed from the acid, as the hydrogen was separated from the oxygen in a former experiment; and I would ask you to observe how the metal behaves when its molecules are thus successively set free. The image of the cell, and of the two wires which dip into the liquid of the cell, are now clearly shown upon the screen. Let us close the circuit, and send the current through the liquid. From one of the wires a beautiful silver tree commences immediately to sprout. Branches of the metal are thrown out, and umbrageous foliage loads the branches. You have here a growth, apparently as wonderful as that of any vegetable, perfected in a minute before your eyes. Substituting for the nitrate of silver acetate of lead, which is a compound of lead and acetic acid, the electric current severs the lead from the acid, and you see the metal slowly branching into exquisite metallic ferns, the fronds of which, as they become too heavy, break from their roots and fall to the bottom of the cell.

These experiments show that the common matter of our earth—'brute matter,' as Dr. Young, in his *Night Thoughts*, is pleased to call it—when its atoms and molecules are permitted to bring their forces into free play, arranges itself, under the operation of these forces, into forms which rival in beauty those of the vegetable world. And what is the vegetable world itself, but the result of the complex play of these molecular forces? Here, as elsewhere throughout nature, if matter moves it is force that moves it, and if a certain structure, vegetable or mineral, is produced, it is through the operation of the forces exerted between the atoms and molecules.

The solid matter of which our lead and silver trees were formed was, in the first instance, disguised in a transparent liquid; the solid matter of which our woods and forests are composed is also, for the most part disguised in a transparent gas, which is mixed in small quantities with the air of our atmosphere. This gas is formed by the union of carbon and oxygen, and is called carbonic acid gas. The carbonic acid of the air being subjected to an action somewhat analogous to that of the electric current in the case of our lead and silver solutions, has its carbon liberated and deposited as woody fibre. The watery vapour of the air is subjected to similar action; its hydrogen is liberated from its oxygen, and lies down side by side with the carbon in the tissues of the tree. The oxygen in both cases is permitted to wander away into the atmosphere. But what is it in nature that plays the part of the electric current in our experiments, tearing asunder the locked atoms of carbon, oxygen, and hydrogen? The rays of the sun. The leaves of plants which absorb both the carbonic acid and the aqueous vapour of the air, answer to the cells in which our decompositions took place. And just as the molecular attractions of the silver and the lead found expression in those beautiful branching forms seen in our experiments, so do the molecular attractions of the liberated carbon and hydrogen find expression in the architecture of grasses, plants, and trees.

In the fall of a cataract and the rush of the wind we have examples of mechanical power. In the combinations of chemistry and in the formation of crystals and vegetables we have examples of molecular power. You have learned how the atoms of oxygen and hydrogen rush together to form water. I have not thought it necessary to dwell upon the mighty mechanical energy of their act of combination; but it may be said, in passing, that the clashing together of 1 lb. of hydrogen and 8 lbs. of oxygen to form 9 lbs. of aqueous vapour, is greater than the shock of a weight of 1,000 tons falling from a height of 20 feet against the earth. Now, in order that the atoms of oxygen and hydrogen should rise by their mutual attractions to the velocity corresponding to this enormous mechanical effect, a certain distance must exist between the particles. It is in rushing over this that the velocity is attained.

This idea of distance between the attracting atoms is of the highest importance in our conception of the system of the world. For the matter of the world may be classified under two distinct heads: atoms and molecules which have already combined and thus satisfied their mutual attractions, and atoms and molecules which have not yet combined, and whose mutual attractions are, therefore, unsatisfied. Now, as regards motive power, we are entirely dependent on atoms and molecules of the latter kind. Their attractions can produce motion, because sufficient distance intervenes between the attracting atoms, and it is this atomic motion that we utilise in our machines. Thus we can get power out of oxygen and hydrogen by the act of their union; but once they are combined, and once the vibratory motion consequent on their combination has been expended, no further power can be got out of their mutual attraction. As dynamic agents they are dead. The materials of the earth's crust consist for the most part of substances whose atoms have already closed in chemical union—whose mutual attractions are satisfied. Granite, for instance, is a widely diffused substance; but granite consists, in great part, of silicon, oxygen, potassium, calcium, and aluminum, whose atoms united long ago, and are therefore dead. Limestone is composed of carbon, oxygen, and a metal called calcium, the atoms of which have already closed in chemical union, and are therefore finally at rest. In this way we might go over nearly the whole of the materials of the earth's crust, and satisfy ourselves that though they were sources of power in ages past, and long before any creature appeared on the earth capable of turning their power to account, they are sources of power no longer. And here we might halt for a moment to remark on that tendency, so prevalent in the world, to regard everything as made for human use. Those who entertain this notion, hold, I think, an overweening opinion of their own importance in the system of nature. Flowers bloomed before men saw them, and the quantity of power wasted before man could utilise it is all but infinite compared with what now remains. We are truly heirs of all the ages; but as honest men it behoves us to learn the extent of our inheritance, and as brave ones not to whimper if it should prove less than we had supposed. The healthy attitude of mind with reference to this subject is that of the poet, who, when asked whence came the rhodora, joyfully acknowledged his brotherhood with the flower—

> Why thou wert there, O rival of the rose!
> I never thought to ask, I never knew,
> But in my simple ignorance supposed
> The self-same power that brought me there brought you.[1]

A few exceptions to the general state of union of the molecules of the earth's crust—vast in relation to us, but trivial in comparison to the total store of which they are the residue—still remain. They constitute our main sources of motive power. By far the most important of these are our beds of coal. Distance still intervenes between the atoms of carbon and those of atmospheric oxygen, across which the atoms may be urged by their mutual attractions; and we can utilise the motion thus produced. Once the carbon and the oxygen have rushed together, so as to form carbonic acid, their mutual attractions are satisfied; and, while they continue in this condition, as dynamic agents they are dead. Our woods and forests are also sources of mechanical energy, because they have the power of uniting with the atmospheric oxygen. Passing from plants to animals, we find that the source of motive power just referred to is also the source of muscular power. A horse can perform work, and so can a man; but this work is at bottom the molecular work of the transmuted food and the oxygen of the air. We inhale this vital gas, and bring it into sufficiently close proximity with the carbon and the hydrogen of the body. These unite in obedience to their mutual attractions; and their motion towards each other, properly turned to account by the wonderful mechanism of the body, becomes muscular motion.

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[1] Emerson.

One fundamental thought pervades all these statements: there is one tap root from which they all spring. This is the ancient maxim that out of nothing nothing comes; that neither in the organic world nor in the inorganic is power produced without the expenditure of power; that neither in the plant nor in the animal is there a creation of force or motion. Trees grow, and so do men and horses; and here we have new power incessantly introduced upon the earth. But its source, as I have already stated, is the sun. It is the sun that separates the carbon from the oxygen of the carbonic acid, and thus enables them to recombine. Whether they recombine in the furnace of the steam-engine or in the animal body, the origin of the power they produce is the same. In this sense we are all 'souls of fire and children of the sun.' But, as remarked by Helmholtz, we must be content to share our celestial pedigree with the meanest of living things.

Some estimable persons, here present, very possibly shrink from accepting these statements; they may be frightened by their apparent tendency towards what is called materialism—a word which, to many minds, expresses something very dreadful. But it ought to be known and avowed that the physical philosopher, as such, must be a pure materialist. His enquiries deal with matter and force, and with them alone. And whatever be the forms which matter and force assume, whether in the organic world or the inorganic, whether in the coal-beds and forests of the earth, or in the brains and muscles of men, the physical philosopher will make good his right to investigate them. It is perfectly vain to attempt to stop enquiry in this direction. Depend upon it, if a chemist by bringing the proper materials together, in a retort or crucible, could make a baby, he would do it. There is no law, moral or physical, forbidding him to do it. At the present moment there are, no doubt, persons experimenting on the possibility of producing what we call life out of inorganic materials. Let them pursue their studies in peace; it is only by such trials that they will learn the limits of their own powers and the operation of the laws of matter and force.

But while thus making the largest demand for freedom of investigation—while I consider science to be alike powerful as an instrument of intellectual culture and as a ministrant to the material wants of men; if you ask me whether it has solved, or is likely in our day to solve, the problem of this universe, I must shake my head in doubt. You remember the first Napoleon's question, when the *savans* who accompanied him to Egypt discussed in his presence the origin of the universe, and solved it to their own apparent satisfaction. He looked aloft to the starry heavens, and said, 'It is all very well, gentlemen; but who made these?' That question still remains unanswered, and science makes no attempt to answer it. As far as I can see, there is no quality in the human intellect which is fit to be applied to the solution of the problem. It entirely transcends us. The mind of man may be compared to a musical instrument with a certain range of notes, beyond which in both directions we have an infinitude of silence. The phenomena of matter and force lie within our intellectual range, and as far as they reach we will at all hazards push our enquiries. But behind, and above, and around all, the real mystery of this universe lies unsolved, and, as far as we are concerned, is incapable of solution. Fashion this mystery as you will, with that I have nothing to do. But let your conception of it not be an unworthy one. Invest that conception with your highest and holiest thought, but be careful of pretending to know more about it than is given to man to know. Be careful, above all things, of professing to see in the phenomena of the material world the evidences of Divine pleasure or displeasure. Doubt those who would deduce from the fall of the tower of Siloam the anger of the Lord against those who were crushed. Doubt equally those who pretend to see in cholera, cattle-plague, and bad harvests, evidences of Divine anger. Doubt those spiritual guides who in Scotland have lately propounded the monstrous theory that the depreciation of railway scrip is a consequence of railway travelling on Sundays. Let them not, as far as you are concerned, libel the system of nature with their ignorant hypotheses. Looking from the solitudes of thought into this highest of questions, and seeing the puerile attempts often made to solve it, well might the mightiest of living Scotchmen—that strong and earnest soul, who has made every soul of like nature in these islands his debtor—well, I say, might your noble old Carlyle scornfully retort on such interpreters of the ways of God to men :—

> The Builder of this universe was wise,
>   He formed all souls, all systems, planets, particles ;
> The plan he formed his worlds and Æons by,
>   Was—Heavens !—was thy small nine-and-thirty articles !

Here, indeed, we arrive at the barrie which needs to be perpetually pointed out; alike to those who seek materialistic explanations of mental phenomena, and to those who are alarmed lest such explanations may be found. The last class prove by their fear, almost as much as the first prove by their hope, that they believe Mind may possibly be interpreted in terms of Matter; whereas many whom they vituperate as materialists are profoundly convinced that there is not the remotest possibility of so interpreting them. —HERBERT SPENCER.

VI.

SCIENTIFIC MATERIALISM.[1]

1868.

THE celebrated Fichte, in his lectures on the 'Vocation of the Scholar,' insisted on a culture which should be not one-sided, but all-sided. The scholar's intellect was to expand spherically, and not in a single direction only. In one direction, however, Fichte required that the scholar should apply himself directly to nature, become a creator of knowledge, and thus repay, by original labours of his own, the immense debt he owed to the labours of others. It was these which enabled him to supplement the knowledge derived from his own researches, so as to render his culture rounded and not one-sided.

As regards science, Fichte's idea is to some extent illustrated by the constitution and labours of the British

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[1] President's Address to the Mathematical and Physical Section of the British Association at Norwich.

Association. We have here a body of men engaged in the pursuit of Natural Knowledge, but variously engaged. While sympathising with each of its departments, and supplementing his culture by knowledge drawn from all of them, each student amongst us selects one subject for the exercise of his own original faculty —one line, along which he may carry the light of his private intelligence a little way into the darkness by which all knowledge is surrounded. Thus, the geologist deals with the rocks; the biologist with the conditions and phenomena of life; the astronomer with stellar masses and motions; the mathematician with the relations of space and number; the chemist pursues his atoms; while the physical investigator has his own large field in optical, thermal, electrical, acoustical, and other phenomena. The British Association then, as a whole, faces physical nature on all sides, and pushes knowledge centrifugally outwards, the sum of its labours constituting what Fichte might call the *sphere* of natural knowledge. In the meetings of the Association it is found necessary to resolve this sphere into its component parts, which take concrete form under the respective letters of our Sections.

Mathematics and Physics have been long accustomed to coalesce, and here they form a single section. No matter how subtle a natural phenomenon may be, whether we observe it in the region of sense, or follow it into that of imagination, it is in the long run reducible to mechanical laws. But the mechanical data once guessed or given, mathematics are all-powerful as an instrument of deduction. The command of Geometry over the relations of space, and the far-reaching power which Analysis confers, are potent both as means of physical discovery, and of reaping the entire fruits of discovery. Indeed, without mathematics, expressed or implied, our knowledge of physical science would be both friable and incomplete.

Side by side with the mathematical method we have the method of experiment. Here from a starting-point furnished by his own researches or those of others, the investigator proceeds by combining intuition and verification. He ponders the knowledge he possesses, and tries to push it further; he guesses, and checks his guess; he conjectures, and confirms or explodes his conjecture. These guesses and conjectures are by no means leaps in the dark; for knowledge once gained casts a faint light beyond its own immediate boundaries. There is no discovery so limited as not to illuminate something beyond itself. The force of intellectual penetration into this penumbral region which surrounds actual knowledge is not, as some seem to think, dependent upon method, but upon the genius of the investigator. There is, however, no genius so gifted as not to need control and verification. The profoundest minds know best that Nature's ways are not at all times their ways, and that the brightest flashes in the world of thought are incomplete until they have been proved to have their counterparts in the world of fact. Thus the vocation of the true experimentalist may be defined as the continued exercise of spiritual insight, and its incessant correction and realisation. His experiments constitute a body, of which his purified intuitions are, as it were, the soul.

Partly through mathematical and partly through experimental research, physical science has, of late years, assumed a momentous position in the world. Both in a material and in an intellectual point of view it has produced, and it is destined to produce, immense changes—vast social ameliorations, and vast alterations in the popular conception of the origin, rule, and governance of natural things. By science, in the physical world, miracles are wrought, while philosophy is forsaking its ancient metaphysical channels, and pursuing others which have been opened, or indicated by, scientific research. This must become more and more the case as philosophical writers become more deeply imbued with the methods of science, better acquainted with the facts which scientific men have established, and with the great theories which they have elaborated.

If you look at the face of a watch, you see the hour and minute-hands, and possibly also a second-hand, moving over the graduated dial. Why do these hands move? and why are their relative motions such as they are observed to be? These questions cannot be answered without opening the watch, mastering its various parts, and ascertaining their relationship to each other. When this is done, we find that the observed motion of the hands follows of necessity from the inner mechanism of the watch when acted upon by the force invested in the spring. The motion of the hands may be called a phenomenon of art, but the case is similar with the phenomena of nature. These also have their inner mechanism and their store of force to set that mechanism going. The ultimate problem of physical science is to reveal this mechanism, to discern this store, and to show that from the combined action of both, the phenomena of which they constitute the basis, must, of necessity, flow.

I thought an attempt to give you even a brief and sketchy illustration of the manner in which scientific thinkers regard this problem, would not be uninteresting to you on the present occasion; more especially as it will give me occasion to say a word or two on the tendencies and limits of modern science; to point out the region which men of science claim as their own, and where it is futile to oppose their advance; and also to define, if possible, the bourne between this and that other region, to which the questionings and yearnings of the scientific intellect are directed in vain.

But here your tolerance will be needed. It was the American Emerson, I think, who said that it is hardly possible to state any truth strongly, without apparent injustice to some other truth. Truth is often of a dual character, taking the form of a magnet with two poles; and many of the differences which agitate the thinking part of mankind are to be traced to the exclusiveness with which partisan reasoners dwell upon one half of the duality, in forgetfulness of the other. The proper course appears to be to state both halves strongly, and allow each its fair share in the formation of the resultant conviction. But this waiting for the statement of the two sides of a question implies patience. It implies a resolution to suppress indignation, if the statement of the one half should clash with our convictions; and to repress equally undue elation, if the half-statement should happen to chime in with our views. It implies a determination to wait calmly for the statement of the whole, before we pronounce judgment in the form of either acquiescence or dissent.

This premised, and I trust accepted, let us enter upon our task. There have been writers who affirmed that the Pyramids of Egypt were natural productions; and in his early youth Alexander von Humboldt wrote a learned essay with the express object of refuting this notion. We now regard the pyramids as the work of men's hands, aided probably by machinery of which no record remains. We picture to ourselves the swarming workers toiling at those vast erections, lifting the inert stones, and, guided by the volition, the skill, and possibly at times by the whip of the architect, placing them in their proper positions. The blocks, in this case, were moved and posited by a power external to themselves, and the final form of the pyramid expressed the thought of its human builder.

Let us pass from this illustration of constructive power to another of a different kind. When a solution of common salt is slowly evaporated, the water which holds the salt in solution disappears, but the salt itself remains behind. At a certain stage of concentration the salt can no longer retain the liquid form; its particles, or molecules, as they are called, begin to deposit themselves as minute solids—so minute, indeed, as to defy all microscopic power. As evaporation continues, solidification goes on, and we finally obtain, through the clustering together of innumerable molecules, a finite crystalline mass of a definite form. What is this form? It sometimes seems a mimicry of the architecture of Egypt. We have little pyramids built by the salt, terrace above terrace from base to apex, forming a series of steps resembling those up which the traveller in Egypt is dragged by his guides. The human mind is as little disposed to look without questioning at these pyramidal salt-crystals, as to look at the pyramids of Egypt, without enquiring whence they came. How, then, are those salt-pyramids built up?

Guided by analogy, you may, if you like, suppose that, swarming among the constituent molecules of the salt, there is an invisible population, controlled and coerced by some invisible master, placing the atomic blocks in their positions. This, however, is not the scientific idea, nor do I think your good sense will accept it as a likely one. The scientific idea is, that the molecules act upon each other without the intervention of slave labour; that they attract each other, and repel each other, at certain definite points, or poles, and in certain definite directions; and that the pyramidal form is the result of this play of attraction and repulsion. While, then, the blocks of Egypt were laid down by a power external to themselves, these molecular blocks of salt are self-posited, being fixed in their places by the inherent forces with which they act upon each other.

I take common salt as an illustration, because it is so familiar to us all; but any other crystalline substance would answer my purpose equally well. Everywhere, in fact, throughout inorganic nature, we have this formative power, as Fichte would call it—this structural energy ready to come into play, and build the ultimate particles of matter into definite shapes. The ice of our winters, and of our polar regions, is its handiwork, and so also are the quartz, felspar, and mica of our rocks. Our chalk-beds are for the most part composed of minute shells, which are also the product of structural energy; but behind the shell, as a whole, lies a more remote and subtle formative act. These shells are built up of little crystals of calc-spar, and, to form these crystals, the structural force had to deal with the intangible molecules of carbonate of lime. This tendency on the part of matter to organise itself, to grow into shape, to assume definite forms in obedience to the definite action of force, is, as I have said, all-pervading. It is in the ground on which you tread, in the water you drink, in the air you breathe. Incipient life, as it were, manifests itself throughout the whole of what we call inorganic nature.

The forms of the minerals resulting from this play of polar forces are various, and exhibit different degrees of complexity. Men of science avail themselves of all possible means of exploring their molecular architecture. For this purpose they employ in turn, as agents of exploration, light, heat, magnetism, electricity, and sound. Polarised light is especially useful and powerful here. A beam of such light, when sent in among the molecules of a crystal, is acted on by them, and from this action we infer with more or less clearness the manner in which the molecules are arranged. That differences, for example, exist between the inner structure of rock-salt and that of crystallised sugar or sugar-candy, is thus strikingly revealed. These actions often display themselves in chromatic phenomena of great splendour, the play of molecular force being so regulated as to cause the removal of some of the coloured constituents of white light, while others are left with increased intensity behind.

And now let us pass from what we are accustomed to regard as a dead mineral, to a living grain of corn. When this is examined by polarised light, chromatic phenomena similar to those noticed in crystals are observed. And why? Because the architecture of the grain resembles that of the crystal. In the grain also the molecules are set in definite positions, and in accordance with their arrangement they act upon the light. But what has built together the molecules of the corn? Regarding crystalline architecture, I have already said that you may, if you please, consider the atoms and molecules to be placed in position by a Power external to themselves. The same hypothesis is open to you now. But if in the case of crystals you have rejected this notion of an external architect, I think you are bound to reject it in the case of the grain, and to conclude that the molecules of the corn, also, are posited by the forces with which they act upon each other. It would be poor philosophy to invoke an external agent in the one case, and to reject it in the other.

Instead of cutting our grain of corn into slices and subjecting it to the action of polarised light, let us place it in the earth, and subject it to a certain degree of warmth. In other words, let the molecules, both of the corn and of the surrounding earth, be kept in that state of agitation which we call heat. Under these circumstances, the grain and the substances which surround it interact, and a definite molecular architecture is the result. A bud is formed; this bud reaches the surface, where it is exposed to the sun's rays, which are also to be regarded as a kind of vibratory motion. And as the motion of common heat, with which the grain and the substances surrounding it were first endowed, enabled the grain and these substances to exercise their mutual attractions and repulsions, and thus to coalesce in definite forms, so the specific motion of the sun's rays now enables the green bud to feed upon the carbonic acid and the aqueous vapour of the air. The bud appropriates those constituents of both for which it has an elective attraction, and permits the other constituent to return to the atmosphere. Thus the architecture is carried on. Forces are active at the root, forces are active in the blade, the matter of the air and the matter of the atmosphere are drawn upon, and the plant augments in size. We have in succession the stalk, the ear, the full corn in the ear; the cycle of molecular action being completed by the production of grains, similar to that with which the process began.

Now there is nothing in this process which necessarily eludes the conceptive or imagining power of the human mind. An intellect the same in kind as our own would, if only sufficiently expanded, be able to follow the whole process from beginning to end. It would see every molecule placed in its position by the specific attractions and repulsions exerted between it and other molecules, the whole process, and its consummation, being an instance of the play of molecular force. Given the grain and its environment, with their respective forces, the purely human intellect might, if sufficiently expanded, trace out *à priori* every step of the process of growth, and, by the application of purely mechanical principles, demonstrate that the cycle must end, as it is seen to end, in the reproduction of forms like that with which it began. A necessity rules here, similar to that which rules the planets in their circuits round the sun.

You will notice that I am stating the truth strongly, as at the beginning we agreed it should be stated. But I must go still further, and affirm that in the eye of science the animal body is just as much the product of molecular force as the chalk and the ear of corn, or as the crystal of salt or sugar. Many of the parts of the body are obviously mechanical. Take the human heart, for example, with its system of valves, or take the exquisite mechanism of the eye or hand. Animal heat, moreover, is the same in kind as the heat of a fire, being produced by the same chemical process. Animal motion, too, is as certainly derived from the food of the animal, as the motion of Trevethyck's walking-engine from the fuel in its furnace. As regards matter, the animal body creates nothing; as regards force, it creates nothing. Which of you by taking thought can add one cubit to his stature? All that has been said, then, regarding the plant, may be restated with regard to the animal. Every particle that enters into the composition of a nerve, a muscle, or a bone has been placed in its position by molecular force. And unless the existence of law in these matters be denied, and the element of caprice introduced, we must conclude that, given the relation of any molecule of the body to its environment, its position in the body might be determined mathematically. Our difficulty is not with the *quality* of the problem, but with its *complexity*; and this difficulty might be met by the simple expansion of the faculties we now possess. Given this expansion, with the necessary molecular data, and the chick might be deduced as rigorously and as logically from the egg, as the existence of Neptune from the disturbances of Uranus, or as conical refraction from the undulatory theory of light.

You see I am not mincing matters, but avowing nakedly what many scientific thinkers more or less distinctly believe. The formation of a crystal, a plant, or an animal, is, in their eyes, a purely mechanical problem, which differs from the problems of ordinary mechanics, in the smallness of the masses, and the complexity of the processes involved. Here you have one half of our dual truth; let us now glance at the other half. Associated with this wonderful mechanism of the animal body we have phenomena no less certain than those of physics, but between which and the mechanism we discern no necessary connection. A man, for example, can say 'I feel,' 'I think,' 'I love;' but how does *consciousness* infuse itself into the problem? The human brain is said to be the organ of thought and feeling: when we are hurt, the brain feels it; when we ponder, or when our passions or affections are excited, it is through the instrumentality of the brain. Let us endeavour to be a little more precise here. I hardly imagine there exists a profound scientific thinker, who has reflected upon the subject, unwilling to admit the extreme probability of the hypothesis, that for every fact of consciousness, whether in the domain of sense, thought, or emotion, a definite molecular condition, of motion or structure, is set up in the brain; or who would be disposed even to deny that if the motion, or structure, be induced by internal causes instead of external, the effect on consciousness will be the same? Let any nerve, for example, be thrown by morbid action into the precise state of motion which would be communicated to it by the pulses of a heated body, surely that nerve will declare itself hot—the mind will accept the subjective intimation exactly as if it were objective. The retina may be excited by purely mechanical means. A blow on the eye causes a luminous flash, and the mere pressure of the finger on the external ball produces a star of light, which Newton compared to the circles on a peacock's tail. Disease makes people see visions and dream dreams; but, in all such cases, could we examine the organs implicated, we should, on philosophical grounds, expect to find them in that precise molecular condition which the real objects, if present, would superinduce.

The relation of physics to consciousness being thus invariable, it follows that, given the state of the brain, the corresponding thought or feeling might be inferred: or, given the thought or feeling, the corresponding state of the brain might be inferred. But how inferred? It would be at bottom not a case of logical inference at all, but of empirical association. You may reply, that many of the inferences of science are of this character —the inference, for example, that an electric current, of a given direction, will deflect a magnetic needle in a definite way. But the cases differ in this, that the passage from the current to the needle, if not demonstrable, is conceivable, and that we entertain no doubt as to the final mechanical solution of the problem. But the passage from the physics of the brain to the corresponding facts of consciousness is inconceivable as a result of mechanics. Granted that a definite thought, and a definite molecular action in the brain, occur simultaneously; we do not possess the intellectual organ, nor apparently any rudiment of the organ, which would enable us to pass, by a process of reasoning, from the one to the other. They appear together, but we do not know why. Were our minds and senses so expanded, strengthened, and illuminated, as to enable us to see and feel the very molecules of the brain; were we capable of following all their motions, all their groupings, all their electric discharges, if such there be; and were we intimately acquainted with the corresponding states of thought and feeling, we should be as far as ever from the solution of the problem, 'How are these physical processes connected with the facts of consciousness?' The chasm between the two classes of phenomena would still remain intellectually impassable. Let the consciousness of love, for example, be associated with a right-handed spiral motion of the molecules of the brain, and the consciousness of hate with a left-handed spiral motion. We should then know, when we love, that the motion is in one direction, and, when we hate, that the motion is in the other; but the 'WHY?' would remain as unanswerable as before.

In affirming that the growth of the body is mechanical, and that thought, as exercised by us, has its correlative in the physics of the brain, I think the position of the 'Materialist' is stated, as far as that position is a tenable one. I think the materialist will be able finally to maintain this position against all attacks; but I do not think, in the present condition of the human mind, that he can pass beyond this position. I do not think he is entitled to say that his molecular groupings, and motions, explain everything.

In reality they explain nothing. The utmost he can affirm is the association of two classes of phenomena, of whose real bond of union he is in absolute ignorance. The problem of the connection of body and soul is as insoluble, in its modern form, as it was in the pre-scientific ages. Phosphorus is known to enter into the composition of the human brain, and a trenchant German writer has exclaimed, 'Ohne Phosphor, kein Gedanke!' That may or may not be the case; but even if we knew it to be the case, the knowledge would not lighten our darkness. On both sides of the zone here assigned to the materialist he is equally helpless. If you ask him whence is this 'Matter' of which we have been discoursing—who or what divided it into molecules, who or what impressed upon them this necessity of running into organic forms—he has no answer. Science is mute in reply to these questions. But if the materialist is confounded and science rendered dumb, who else is prepared with a solution? To whom has this arm of the Lord been revealed? Let us lower our heads, and acknowledge our ignorance, priest and philosopher, one and all.

Perhaps the mystery may resolve itself into knowledge at some future day. The process of things upon this earth has been one of amelioration. It is a long way from the Iguanodon and his contemporaries, to the President and Members of the British Association. And whether we regard the improvement from the scientific or from the theological point of view—as the result of progressive development, or of successive exhibitions of creative energy—neither view entitles us to assume that man's present faculties end the series, that the process of amelioration ends with him. A time may therefore come when this ultra-scientific region, by which we are now enfolded, may offer itself to terrestrial, if not to human, investigation. Two-thirds of the rays emitted by the sun fail to arouse the sense of vision. The rays exist, but the visual organ requisite for their translation into light does not exist. And so from this region of darkness and mystery which surrounds us, rays may now be darting, which require but the development of the proper intellectual organs to translate them into knowledge as far surpassing ours, as ours surpasses that of the wallowing reptiles which once held possession of this planet. Meanwhile the mystery is not without its uses. It certainly may be made a power in the human soul; but it is a power which has feeling, not knowledge, for its base. It may be, will be, and I hope is turned to account, both in steadying and strengthening the intellect, and in rescuing man from that littleness to which, in the struggle for existence, or for precedence in the world, he is continually prone.

Musings on the Matterhorn, July 27, 1868.

Hacked and hurt by time, the aspect of the mountain from its higher crags saddened me. Hitherto the impression it made was that of savage strength; here we had inexorable decay. But this notion of decay implied a reference to a period when the Matterhorn was in the full strength of mountainhood. Thought naturally ran back to its remoter origin and sculpture. Nor did thought halt there, but wandered on through molten worlds to that nebulous haze which philosophers have regarded, and with good reason, as the proximate source of all material things. I tried to look at this universal cloud, containing within itself the prediction of all that has since occurred; I tried to imagine it as the seat of those forces whose action was to issue in solar and stellar systems, and all that they involve. Did that formless fog contain potentially the *sadness* with which I regarded the Matterhorn? Did the *thought* which now ran back to it simply return to its primeval home? If so, had we not better recast our definitions of matter and force; for, if life and thought be the very flower of both, any definition which omits life and thought must be inadequate, if not untrue. Are questions like these warranted? Why not? If the final goal of man has not been yet attained; if his development has not been yet arrested, who can say that such yearnings and questionings are not necessary to the opening of a finer vision, to the budding and the growth of diviner powers? When I look at the heavens and the earth, at my own body, at my strength and weakness, even at these ponderings, and ask myself, Is there no being or thing in the universe that knows more about these matters than I do; what is my answer? Supposing our theologic schemes of creation, condemnation, and redemption to be dissipated; and the warmth of denial which they excite, and which, as a motive force, can match the warmth of affirmation, dissipated at the same time; would the undeflected human mind return to the meridian of absolute neutrality as regards these ultra-physical questions? Is such a position one of stable equilibrium? The channels of thought being already formed, such are the questions, without replies, which could run athwart consciousness during a ten minutes' halt upon the weathered crest of the Matterhorn.

Self-reverence, self-knowledge, self-control,
These three alone lead life to sovereign power,
Yet not for power (power of herself
Would come uncalled for), but to live by law,
Acting the law we live by without fear;
And, because right is right, to follow right
Were wisdom in the scorn of consequence.

TENNYSON.

VII.

AN ADDRESS TO STUDENTS.[1]

THERE is an idea regarding the nature of man which modern philosophy has sought, and is still seeking, to raise into clearness; the idea, namely, of secular growth. Man is not a thing of yesterday; nor do I imagine that the slightest controversial tinge is imported into this address when I say that he is not a thing of 6,000 years ago. Whether he came originally from stocks or stones, from nebulous gas or solar fire, I know not; if he had any such origin the process of his transformation is as inscrutable to you and me as that of the grand old legend, according to which 'the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life; and man became a living soul.' But however obscure man's origin may be, his growth is not to be denied. Here a little and there a little added through the ages have slowly transformed him from what he was into what he is. The doctrine has been held that the mind of the child is like a sheet of white paper, on which by education we can write what characters we please. This doctrine assuredly needs qualification and correction. In physics, when an external force is applied to a body with a view of affecting its inner texture, if we wish to predict the result, we must know whether the external force conspires with or opposes the internal forces of the body itself; and in bringing the influence of education to bear upon the new-born man his inner powers also must be taken into account. He comes to us as a bundle of inherited capacities and tendencies, labelled 'from the indefinite past to the indefinite future;' and he makes his transit from the one to the other through the education of the present time. The object of that education is, or ought to be, to provide wise exercise for his capacities, wise direction for his tendencies, and through this exercise and this direction to furnish his mind with such knowledge as may contribute to the usefulness, the beauty, and the nobleness of his life.

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[1] Delivered at University College, London, Session 1868–69.

How is this discipline to be secured, this knowledge imparted? Two rival methods now solicit attention,—the one organised and equipped, the labour of centuries having been expended in bringing it to its present state of perfection; the other, more or less chaotic, but becoming daily less so, and giving signs of enormous power, both as a source of knowledge and as a means of discipline. These two methods are the classical and the scientific method. I wish they were not rivals; it is only bigotry and short-sightedness that make them so; for assuredly it is possible to give both of them fair play. Though hardly authorised to express an opinion upon the subject, I nevertheless hold the opinion that the proper study of a language is an intellectual discipline of the highest kind. If I except discussions on the comparative merits of Popery and Protestantism, English grammar was the most important discipline of my boyhood. The piercing through the involved and inverted sentences of 'Paradise Lost'; the linking of the verb to its often distant nominative, of the relative to its distant antecedent, of the agent to the object of the transitive verb, of the preposition to the noun or pronoun which it governed, the study of variations in mood and tense, the transpositions often necessary to bring out the true grammatical structure of a sentence, —all this was to my young mind a discipline of the highest value, and a source of unflagging delight. How I rejoiced when I found a great author tripping, and was fairly able to pin him to a corner from which there was no escape! As I speak, some of the sentences which exercised me when a boy rise to my recollection. For instance, 'He that hath ears to hear, let him hear;' where the 'He' is left, as it were, floating in mid air without any verb to support it. I speak thus of English because it was of real value to me. I do not speak of other languages because their educational value for me was almost insensible. But knowing the value of English so well, I should be the last to deny, or even to doubt, the high discipline involved in the proper study of Latin and Greek.

That study, moreover, has other merits and recommendations. It is, as I have said, organised and systematised by long-continued use. It is an instrument wielded by some of our best intellects in the education of youth; and it can point to results in the achievements of our foremost men. What, then, has science to offer which is in the least degree likely to compete with such a system? I cannot better reply than by recurring to the grand old story from which I have already quoted. Speaking of the world and all that therein is, of the sky and the stars around it, the ancient writer says, 'And God saw all that he had made, and behold it was very good.' It is the body of things thus described which science offers to the study of man. There is a very renowned argument much prized and much quoted by theologians, in which the universe is compared to a watch. Let us deal practically with this comparison. Supposing a watchmaker, having completed his instrument, to be so satisfied with his work as to call it very good, what would you understand him to mean? You would not suppose that he referred to the dial-plate in front and the chasing of the case behind, so much as to the wheels and pinions, the springs and jewelled pivots of the works within—to those qualities and powers, in short, which enable the watch to perform its work as a keeper of time. With regard to the knowledge of such a watch he would be a mere ignoramus who would content himself with outward inspection. I do not wish to say one severe word here to-day, but I fear that many of those who are very loud in their praise of the works of the Lord know them only in this outside and superficial way. It is the inner works of the universe which science reverently uncovers; it is the study of these that she recommends as a discipline worthy of all acceptation.

The ultimate problem of physics is to reduce matter by analysis to its lowest condition of divisibility, and force to its simplest manifestations, and then by synthesis to construct from these elements the world as it stands. We are still a long way from the final solution of this problem; and when the solution comes, it will be more one of spiritual insight than of actual observation. But though we are still a long way from this complete intellectual mastery of nature, we have conquered vast regions of it, have learned their polities and the play of their powers. We live upon a ball of 8,000 miles in diameter, swathed by an atmosphere of unknown height. This ball has been molten by heat, chilled to a solid, and sculptured by water. It is made up of substances possessing distinctive properties and modes of action, which offer problems to the intellect, some profitable to the child, others taxing the highest powers of the philosopher. Our native sphere turns on its axis, and revolves in space. It is one of a band which all do the same. It is illuminated by a sun which, though nearly a hundred millions of miles distant, can be brought virtually into our closets and there subjected to examination. It has its winds and clouds, its rain and frost, its light, heat, sound, electricity, and magnetism. And it has its vast kingdoms of animals and vegetables. To a most amazing extent the human mind has conquered these things, and revealed the logic which runs through them. Were they facts only, without logical relationship, science might, as a means of discipline, suffer in comparison with language. But the whole body of phenomena is instinct with law; the facts are hung on principles, and the value of physical science as a means of discipline consists in the motion of the intellect, both inductively and deductively, along the lines of law marked out by phenomena. As regards the discipline to which I have already referred as derivable from the study of languages,—that, and more, is involved in the study of physical science. Indeed, I believe it would be possible so to limit and arrange the study of a portion of physics as to render the mental exercise involved in it almost qualitatively the same as that involved in the unravelling of a language.

I have thus far confined myself to the purely intellectual side of this question. But man is not all intellect. If he were so, science would, I believe, be his proper nutriment. But he feels as well as thinks; he is receptive of the sublime and beautiful as well as of the true. Indeed, I believe that even the intellectual action of a complete man is, consciously or unconsciously, sustained by an undercurrent of the emotions. It is vain to attempt to separate the moral and emotional from the intellectual. Let a man but observe himself, and he will, if I mistake not, find that in nine cases out of ten, the emotions constitute the motive force which pushes his intellect into action. The reading of the works of two men, neither of them imbued with the spirit of modern science—neither of them, indeed, friendly to that spirit—has placed me here to-day. These men are the English Carlyle and the American Emerson. I must ever gratefully remember that through three long cold German winters Carlyle placed me in my tub, even when ice was on its surface, at five o'clock every morning—not slavishly, but cheerfully, meeting each day's studies with a resolute will, determined whether victor or vanquished not to shrink from difficulty. I never should have gone through Analytical Geometry and the Calculus had it not been for those men. I never should have become a physical investigator, and hence without them I should not have been here to-day. They told me what I ought to do in a way that caused me to do it, and all my consequent intellectual action is to be traced to this purely moral source. To Carlyle and Emerson I ought to add Fichte, the greatest representative of pure idealism. These three unscientific men made me a practical scientific worker. They called out 'Act!' I hearkened to the summons, taking the liberty, however, of determining for myself the direction which effort was to take.

And I may now cry 'Act!' but the potency of action must be yours. I may pull the trigger, but of the gun be not charged there is no result. We are creators in the intellectual world as little as in the physical. We may remove obstacles, and render latent capacities active, but we cannot suddenly change the nature of man. The 'new birth' itself implies the pre-existence of a character which requires not to be created but brought forth. You cannot by any amount of missionary labour suddenly transform the savage into the civilised Christian. The improvement of man is *secular*—not the work of an hour or of a day. But though indubitably bound by our organisations, no man knows what the potentialities of any human mind may be, requiring only release to be brought into action. There are in the mineral world certain crystals—certain forms, for instance, of fluor-spar, which have lain darkly in the earth for ages, but which nevertheless have a potency of light locked up within them. In their case the potential has never become actual—the light is in fact held back by a molecular detent. When these crystals are warmed, the detent is lifted, and an outflow of light immediately begins. I know not how many of you may be in the condition of this fluor-spar. For aught I know, every one of you may be in this condition, requiring but the proper agent to be applied—the proper word to be spoken—to remove a detent, and to render you conscious of light and warmth within yourselves and sources of both to others.

The circle of human nature, then, is not complete without the arc of the emotions. The lilies of the field have a value for us beyond their botanical ones—a certain lightening of the heart accompanies the declaration that 'Solomon in all his glory was not arrayed like one of these.' The sound of the village bell has a value beyond its acoustical one. The setting sun has a value beyond its optical one. The starry heavens, as you know, had for Immanuel Kant a value beyond their astronomical one. I think it very desirable to keep this horizon of the emotions open, and not to permit either priest or philosopher to draw down his shutters between you and it. Here the dead languages, which are sure to be beaten by science in the purely intellectual fight, have an irresistible claim. They supplement the work of science by exalting and refining the æsthetic faculty, and must on this account be cherished by all who desire to see human culture complete. There must be a reason for the fascination which these languages have so long exercised upon powerful and elevated minds—a fascination which will probably continue for men of Greek and Roman mould to the end of time.

In connection with this question one very obvious danger besets many of the more earnest spirits of our day—the danger of *haste* in endeavouring to give the feelings repose. We are distracted by systems of theology and philosophy which were taught to us when young, and which now excite in us a hunger and a thirst for knowledge not proved to be attainable. There are periods when the judgment ought to remain in suspense, the data on which a decision might be based being absent. This discipline of suspending the judgment is a common one in science, but not so common as it ought to be elsewhere. I walked down Regent Street some time ago with a man of great gifts and acquirements, discussing with him various theological questions. I could not accept his views of the origin and destiny of the universe, nor was I prepared to enunciate any definite views of my own. He turned to me at length and said, 'You surely must have a theory of the universe.' That I should in one way or another have solved this mystery of mysteries seemed to my friend a matter of course. 'I have not even a theory of magnetism' was my reply. We ought to learn to wait. We ought assuredly to pause before closing with the advances of those expounders of the ways of God to men, who offer us intellectual peace at the modest cost of intellectual life.

The teachers of the world ought to be its best men, and for the present at all events such men must learn self-trust. By the fullness and freshness of their own lives and utterances they must awaken life in others. The hopes and terrors which influenced our fathers are passing away, and our trust henceforth must rest on the innate strength of man's moral nature. And here, I think, the poet will have a great part to play in the future culture of the world. To him, when he rightly understands his mission, and does not flinch from the tonic discipline which it assuredly demands, we have a right to look for that heightening and brightening of life which so many of us need. To him it is given for a long time to come to fill those shores which the recession of the theologic tide has left exposed. Void of offence to science, he may freely deal with conceptions which science shuns, and become the illustrator and interpreter of that Power which as

'Jehovah, Jove, or Lord,'

has hitherto filled and strengthened the human heart.

Let me utter one practical word in conclusion—take care of your health. There have been men who by wise attention to this point might have risen to any eminence—might have made great discoveries, written great poems, commanded armies, or ruled states, but who by unwise neglect of this point have come to nothing. Imagine Hercules as oarsman in a rotten boat; what can he do there but by the very force of his stroke expedite the ruin of his craft? Take care then of the timbers of your boat, and avoid all practices likely to introduce either wet or dry rot amongst them. And this is not to be accomplished by desultory or intermittent efforts of the will, but by the formation of *habits*. The will no doubt has sometimes to put forth its strength in order to crush the special temptation. But the formation of right habits is essential to your permanent security. They diminish your chance of falling when assailed, and they augment your chance of recovery when overthrown.

If thou would'st know the mystic song
Chaunted when the sphere was young,
Aloft, abroad, the pæan swells,
O wise man, hear'st thou half it tells?
To the open ear it sings
The early genesis of things;
Of tendency through endless ages
Of star-dust and star-pilgrimages,
Of rounded worlds, of space and time,
Of the old floods' subsiding slime,
Of chemic matter, force and form,
Of poles and powers, cold, wet, and warm.
The rushing metamorphosis
Dissolving all that fixture is,
Melts things that be to things that seem,
And solid nature to a dream.'

EMERSON.

Was wär' ein Gott der nur von aussen stiesse,
Im Kreis das All am Finger laufen liesse
Ihm ziemt's, die Welt im Innern zu bewegen,
Natur in Sich, Sich in Natur zu hegen.'

GOETHE.

VIII.

SCIENTIFIC USE OF THE IMAGINATION.[1]

'Lastly, physical investigation, more than anything besides, helps to teach us the actual value and right use of the Imagination—of that wondrous faculty, which, left to ramble uncontrolled, leads us astray into a wilderness of perplexities and errors, a land of mists and shadows; but which, properly controlled by experience and reflection, becomes the noblest attribute of man; the source of poetic genius, the

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[1] Discourse delivered before the British Association at Liverpool, September 16, 1870.

instrument of discovery in Science, without the aid of which Newton would never have invented fluxions, nor Davy have decomposed the earths and alkalies, nor would Columbus have found another Continent.'—Address to the Royal Society by its President Sir Benjamin Brodie, November 30, 1859.

I CARRIED with me to the Alps this year the burden of this evening's work. Save from memory I had no direct aid upon the mountains; but to spur up the emotions, on which so much depends, as well as to nourish indirectly the intellect and will, I took with me four works, comprising two volumes of poetry, Goethe's 'Farbenlehre,' and the work on 'Logic' recently published by Mr. Alexander Bain. In Goethe, so noble otherwise, I chiefly noticed the self-inflicted hurts of genius, as it broke itself in vain against the philosophy of Newton. Mr. Bain I found, for the most part, learned and practical, shining generally with a dry light, but exhibiting at times a flush of emotional strength, which proved that even logicians share the common fire of humanity. He interested me most when he became the mirror of my own condition. Neither intellectually nor socially is it good for man to be alone, and the sorrows of thought are more patiently borne when we find that they have been experienced by another. From certain passages in his book I could infer that Mr. Bain was no stranger to such sorrows. Speaking for example of the ebb of intellectual force, which we all from time to time experience, Mr. Bain says: 'The uncertainty where to look for the next opening of discovery brings the pain of conflict and the debility of indecision.' These words have in them the true ring of personal experience. The action of the investigator is periodic. He grapples with a subject of enquiry, wrestles with it, and exhausts, it may be, both himself and it for the time being. He breathes a space, and then renews the struggle in another field. Now this period of halting between two investigations is not always one of pure repose. It is often a period of doubt and discomfort—of gloom and ennui. 'The uncertainty where to look for the next opening of discovery brings the pain of conflict and the debility of indecision.' It was under such conditions that I had to equip myself for the hour and the ordeal that are now come.

The disciplines of common life are, in great part, exercises in the relations of space, or in the mental grouping of bodies in space; and, by such exercises, the public mind is, to some extent, prepared for the reception of physical conceptions. Assuming this preparation on your part, the wish gradually grew within me to trace, and to enable you to trace, some of the more occult features and operations of Light and Colour. I wished, if possible, to take you beyond the boundary of mere observation, into a region where things are intellectually discerned, and to show you there the hidden mechanism of optical action.

But how are those hidden things to be revealed? Philosophers may be right in affirming that we cannot transcend experience: we can, at all events, carry it a long way from its origin. We can magnify, diminish, qualify, and combine experiences, so as to render them fit for purposes entirely new. In explaining sensible phenomena, we habitually form mental images of the ultra-sensible. There are Tories even in science who regard Imagination as a faculty to be feared and avoided rather than employed. They have observed its action in weak vessels, and are unduly impressed by its disasters. But they might with equal justice point to exploded boilers as an argument against the use of steam. With accurate experiment and observation to work upon, Imagination becomes the architect of physical theory. Newton's passage from a falling apple to a falling moon was an act of the prepared imagination, without which the 'laws of Kepler' could never have been traced to their foundations. Out of the facts of chemistry the constructive imagination of Dalton formed the atomic theory. Davy was richly endowed with the imaginative faculty, while with Faraday its exercise was incessant, preceding, accompanying and guiding all his experiments. His strength and fertility as a discoverer is to be referred in great part to the stimulus of his imagination. Scientific men fight shy of the word because of its ultra-scientific connotations; but the fact is that without the exercise of this power, our knowledge of nature would be a mere tabulation of co-existences and sequences. We should still believe in the succession of day and night, of summer and winter; but the conception of Force would vanish from our universe; causal relations would disappear, and with them that science which is now binding the parts of nature to an organic whole.

I should like to illustrate by a few simple instances the use that scientific men have already made of this power of imagination, and to indicate afterwards some of the further uses that they are likely to make of it. Let us begin with the rudimentary experiences. Observe the falling of heavy rain-drops into a tranquil pond. Each drop as it strikes the water becomes a centre of disturbance, from which a series of ring-ripples expand outwards. Gravity and inertia are the agents by which this wave-motion is produced, and a rough experiment will suffice to show that the rate of propagation does not amount to a foot a second. A series of slight mechanical shocks is experienced by a body plunged in the water, as the wavelets reach it in succession. But a finer motion is at the same time set up and propagated. If the head and ears be immersed in the water, as in an experiment of Franklin's, the *tick* of the drop is heard. Now, this sonorous impulse is propagated, not at the rate of a foot, but at the rate of 4,700 feet a second. In this case it is not the gravity but the *elasticity* of the water that comes into play. Every liquid particle pushed against its neighbour delivers up its motion with extreme rapidity, and the pulse is propagated as a thrill. The incompressibility of water, as illustrated by the famous Florentine experiment, is a measure of its elasticity; and to the possession of this property, in so high a degree, the rapid transmission of a sound-pulse through water is to be ascribed.

But water, as you know, is not necessary to the conduction of sound; air is its most common vehicle. And you know that when the air possesses the particular density and elasticity corresponding to the temperature of freezing water, the velocity of sound in it is 1,090 feet a second. It is almost exactly one-fourth of the velocity in water; the reason being that though the greater weight of the water tends to diminish the velocity, the enormous molecular elasticity of the liquid far more than atones for the disadvantage due to weight. By various contrivances we can compel the vibrations of the air to declare themselves; we know the length and frequency of the sonorous waves, and we have also obtained great mastery over the various methods by which the air is thrown into vibration. We know the phenomena and laws of vibrating rods, of organ-pipes, strings, membranes, plates, and bells. We can abolish one sound by another. We know the physical meaning of music and noise, of harmony and discord. In short, as regards sound in general, we have a very clear notion of the external physical processes which correspond to our sensations.

In the phenomena of sound, we travel a very little way from downright sensible experience. Still the imagination is to some extent exercised. The bodily eye, for example, cannot see the condensations and rarefactions of the waves of sound. We construct them in thought, and we believe as firmly in their existence as in that of the air itself. But now our experience is to be carried into a new region, where a new use is to be made of it. Having mastered the cause and mechanism of sound, we desire to know the cause and mechanism of light. We wish to extend our enquiries from the auditory to the optic nerve. There is in the human intellect a power of expansion—I might almost call it a power of creation—which is brought into play by the simple brooding upon facts. The legend of the spirit brooding over chaos may have originated in experience of this power. In the case now before us it has manifested itself by transplanting into space, for the purposes of light, an adequately modified form of the mechanism of sound. We know intimately whereon the velocity of sound depends. When we lessen the density of the aërial medium, and preserve its elasticity constant, we augment the velocity. When we heighten the elasticity, and keep the density constant, we also augment the velocity. A small density, therefore, and a great elasticity, are the two things necessary to rapid propagation. Now light is known to move with the astounding velocity of 186,000 miles a second. How is such a velocity to be obtained? By boldly diffusing in space a medium of the requisite tenuity and elasticity.

Let us make such a medium our starting-point, and, endowing it with one or two other necessary qualities, let us handle it in accordance with strict mechanical laws. Let us then carry our results from the world of theory into the world of sense, and see whether our deductions do not issue in the very phenomena of light which ordinary knowledge and skilled experiment reveal. If in all the multiplied varieties of these phenomena, including those of the most remote and entangled description, this fundamental conception always brings us face to face with the truth; if no contradiction to our deductions from it be found in external nature, but on all sides agreement and verification; if, moreover, as in the case of Conical Refraction and in other cases, it actually forces upon our attention phenomena which no eye had previously seen, and which no mind had previously imagined—such a conception, must, we think, be something more than a mere figment of the scientific fancy. In forming it, that composite and creative power, in which reason and imagination are united, has, we believe, led us into a world not less real than that of the senses, and of which the world of sense itself is the suggestion and, to a great extent, the outcome.

Far be it from me, however, to wish to fix you immovably in this or in any other theoretic conception. With all our belief of it, it will be well to keep the theory of a luminiferous ether plastic and capable of change. You may, moreover, urge that, although the phenomena occur *as if* the medium existed, the absolute demonstration of its existence is still wanting. Far be it from me to deny to this reasoning such validity as it may fairly claim. Let us endeavour by means of analogy to form a fair estimate of its force. You believe that in society you are surrounded by reasonable beings like yourself. You are, perhaps, as firmly convinced of this as of anything. What is your warrant for this conviction? Simply and solely this: your fellow-creatures behave as if they were reasonable; the hypothesis, for it is nothing more, accounts for the facts. To take an eminent example: you believe that our President is a reasonable being. Why? There is no known method of superposition by which any one of us can apply himself intellectually to any other, so as to demonstrate coincidence as regards the possession of reason. If, therefore, you hold our President to be reasonable, it is because he behaves *as if* he were reasonable. As in the case of the ether, beyond the '*as if*' you cannot go. Nay, I should not wonder if a close comparison of the data on which both inferences rest, caused many respectable persons to conclude that the ether had the best of it.

This universal medium, this light-ether as it is called, is the vehicle, not the origin, of wave-motion. It receives and transmits, but it does not create. Whence does it derive the motions it conveys? For the most part from luminous bodies. By the motion of a luminous body I do not mean its sensible motion, such as the flicker of a candle, or the shooting out of red prominences from the limb of the sun. I mean an intestine motion of the atoms or molecules of the luminous body. But here a certain reserve is necessary. Many chemists of the present day refuse to speak of atoms and molecules as real things. Their caution leads them to stop short of the clear, sharp, mechanically intelligible atomic theory enunciated by Dalton, or any form of that theory, and to make the doctrine of 'multiple proportions' their intellectual bourne. I respect the caution, though I think it is here misplaced. The chemists who recoil from these notions of atoms and molecules accept, without hesitation, the Undulatory Theory of Light. Like you and me they one and all believe in an ether and its light-producing waves. Let us consider what this belief involves. Bring your imaginations once more into play, and figure a series of sound-waves passing through air. Follow them up to their origin, and what do you there find? A definite, tangible, vibrating body. It may be the vocal chords of a human being, it may be an organ-pipe, or it may be a stretched string. Follow in the same manner a train of ether-waves to their source; remembering at the same time that your ether is matter, dense, elastic, and capable of motions subject to, and determined by, mechanical laws. What then do you expect to find as the source of a series of ether-waves? Ask your imagination if it will accept a vibrating multiple proportion—a numerical ratio in a state of oscillation? I do not think it will. You cannot crown the edifice with this abstraction. The scientific imagination, which is here authoritative, demands, as the origin and cause of a series of ether-waves, a particle of vibrating matter quite as definite, though it may be excessively minute, as that which gives origin to a musical sound. Such a particle we name an atom or a molecule. I think the intellect, when focussed so as to give definition without penumbral haze, is sure to realise this image at the last.

With the view of preserving thought continuous throughout this discourse, and of preventing either failure of knowledge or of memory, from causing any rent in our picture, I here propose to run rapidly over a bit of ground which is probably familiar to most of you, but which I am anxious to make familiar to you all. The waves generated in the ether by the swinging atoms of luminous bodies are of different lengths and amplitudes. The amplitude is the width of swing of the individual particles of the waves. In water-waves it is the vertical height of the crest above the trough, while the length of the wave is the horizontal distance between two consecutive crests. The aggregate of waves emitted by the sun may be broadly divided into two classes: the one class competent, the other incompetent, to excite vision. But the light-producing waves differ markedly among themselves in size, form, and force. The length of the largest of these waves is about twice that of the smallest, but the amplitude of the largest is probably a hundred times that of the smallest. Now the force or energy of the wave, which, expressed with reference to sensation, means the intensity of the light, is proportional to the square of the amplitude. Hence the amplitude being one-hundredfold, the energy of the largest light-giving waves would be ten-thousandfold that of the smallest. This is not improbable. I use these figures not with a view to numerical accuracy, but to give you definite ideas of the differences that probably exist among the light-giving waves. And if we take the whole range of solar radiation into account—its non-visual as well as its visual waves—I think it probable that the force, or energy, of the largest wave is more than a million times that of the smallest.

Turned into their equivalents of sensation, the different light-waves produce different colours. Red, for example, is produced by the largest waves, violet by the smallest, while green is produced by a wave of intermediate length and amplitude. On entering from air into a more highly refracting substance, such as glass or water, or the sulphide of carbon, all the waves are retarded, but the smallest ones most. This furnishes a means of separating the different classes of waves from each other; in other words, of analysing the light.

Sent through a refracting prism, the waves of the sun are turned aside in different degrees from their direct course, the red least, the violet most. They are virtually pulled asunder, and they paint upon a white screen placed to receive them 'the solar spectrum.' Strictly speaking, the spectrum embraces an infinity of colours; but the limits of language, and of our powers of distinction, cause it to be divided into seven segments: red, orange, yellow, green, blue, indigo, violet. These are the seven primary or prismatic colours.

Separately, or mixed in various proportions, the solar waves yield all the colours observed in nature and employed in art. Collectively, they give us the impression of whiteness. Pure unsifted solar light is white; and, if all the wave-constituents of such light be reduced in the same proportion, the light, though diminished in intensity, will still be white. The whiteness of snow with the sun shining upon it, is barely tolerable to the eye. The same snow under an overcast firmament is still white. Such a firmament enfeebles the light by reflecting it upwards; and when we stand above a cloud-field—on an Alpine summit, for instance, or on the top of Snowdon—and see, in the proper direction, the sun shining on the clouds below us, they appear dazzlingly white. Ordinary clouds, in fact, divide the solar light impinging on them into two parts—a reflected part and a transmitted part, in each of which the proportions of wave-motion which produce the impression of whiteness are sensibly preserved.

It will be understood that the condition of whiteness would fail if all the waves were diminished *equally*, or by the same absolute quantity. They must be reduced *proportionately*, instead of equally. If by the act of reflection the waves of red light are split into exact halves, then, to preserve the light white, the waves of yellow, orange, green, and blue, must also be split into exact halves. In short, the reduction must take place, not by absolutely equal quantities, but by equal fractional parts. In white light the preponderance, as regards energy, of the larger over the smaller waves must always be immense. Were the case otherwise, the visual correlative, *blue*, of the smaller waves would have the upper hand in our sensations.

Not only are the waves of ether reflected by clouds, by solids, and by liquids, but when they pass from light air to dense, or from dense air to light, a portion of the wave-motion is always reflected. Now our atmosphere changes continually in density from top to bottom. It will help our conceptions if we regard it as made up of a series of thin concentric layers, or shells of air, each shell being of the same density throughout, a small and sudden change of density occurring in passing from shell to shell. Light would be reflected at the limiting surfaces of all these shells, and their action would be practically the same as that of the real atmosphere. And now I would ask your imagination to picture this act of reflection. What must become of the reflected light? The atmospheric layers turn their convex surfaces towards the sun; they are so many convex mirrors of feeble power; and you will immediately perceive that the light regularly reflected from these surfaces cannot reach the earth at all, but is dispersed in space. Light thus reflected cannot, therefore, be the light of the sky.

But, though the sun's light is not reflected in this fashion from the aërial layers to the earth, there is indubitable evidence to show that the light of our firmament is scattered light. Proofs of the most cogent description could be here adduced; but we need only consider that we receive light at the same time from all parts of the hemisphere of heaven. The light of the firmament comes to us across the direction of the solar rays, and even against the direction of the solar rays; and this lateral and opposing rush of wave-motion can only be due to the rebound of the waves from the air itself, or from something suspended in the air. It is also evident that, unlike the action of clouds, the solar light is not reflected by the sky in the proportions which produce white. The sky is blue, which indicates an excess of the shorter waves. In accounting for the colour of the sky, the first question suggested by analogy would undoubtedly be, Is not the air blue? The blueness of the air has, in fact, been given as a solution of the blueness of the sky. But how, if the air be blue, can the light of sunrise and sunset, which travels through vast distances of air, be yellow, orange, or even red? The passage of white solar light through a blue medium could by no possibility redden the light. The hypothesis of a blue air is therefore untenable. In fact the agent, whatever it is, which sends us the light of the sky, exercises in so doing a dichroitic action. The light reflected is blue, the light transmitted is orange or red. A marked distinction is thus exhibited between the matter of the sky, and that of an ordinary cloud, which exercises no such dichroitic action.

By the scientific use of the imagination we may hope to penetrate this mystery. The cloud takes no note of size on the part of the waves of ether, but reflects them all alike. It exercises no selective action. Now the cause of this may be that the cloud particles are so large, in comparison with the waves of ether, as to reflect them all indifferently. A broad cliff reflects an Atlantic roller as easily as a ripple produced by a sea-bird's wing; and in the presence of large reflecting surfaces, the existing differences of magnitude among the waves of ether may disappear. But supposing the reflecting particles, instead of being very large, to be very small in comparison with the size of the waves. In this case, instead of the whole wave being fronted and thrown back, a small portion only is shivered off. The great mass of the wave passes over such a particle without reflection. Scatter, then, a handful of such minute foreign particles in our atmosphere, and set imagination to watch their action upon the solar waves. Waves of all sizes impinge upon the particles, and you see at every collision a portion of the impinging wave struck off; all the waves of the spectrum, from the extreme red to the extreme violet, being thus acted upon.

Remembering that the red waves stand to the blue much in the relation of billows to ripples, we have to consider whether those extremely small particles are competent to scatter all the waves in the same proportion. If they be not—and a little reflection will make it clear that they are not—the production of colour must be an incident of the scattering. Largeness is a thing of relation; and the smaller the wave, the greater is the relative size of any particle on which the wave impinges, and the greater also the ratio of the portion scattered to the total wave. A pebble, placed in the way of the ring-ripples produced by heavy raindrops on a tranquil pond, will scatter a large fraction of each ripple, while the fractional part of a larger wave thrown back by the same pebble might be infinitesimal. Now we have already made it clear to our minds that to preserve the solar light white, its constituent proportions must not be altered; but in the act of division performed by these very small particles the proportions *are* altered; an undue fraction of the smaller waves is scattered by the particles, and, as a consequence, in the scattered light, blue will be the predominant colour. The other colours of the spectrum must, to some extent, be associated with the blue. They are not absent, but deficient. We ought, in fact, to have them all, but in diminishing proportions, from the violet to the red.

We have here presented a case to the imagination, and, assuming the undulatory theory to be a reality, we have, I think, fairly reasoned our way to the conclusion, that were particles, small in comparison to the sizes of the ether waves, sown in our atmosphere, the light scattered by those particles would be exactly such as we observe in our azure skies. When this light is analysed, all the colours of the spectrum are found, and they are found in the proportions indicated by our conclusion. Blue is not the sole, but it is the predominant colour.

Let us now turn our attention to the light which passes unscattered among the particles. How must it be finally affected? By its successive collisions with the particles the white light is more and more robbed of its shorter waves; it therefore loses more and more of its due proportion of blue. The result may be anticipated. The transmitted light, where short distances are involved, will appear yellowish. But as the sun sinks towards the horizon the atmospheric distances increase, and consequently the number of the scattering particles. They abstract in succession the violet, the indigo, the blue, and even disturb the proportions of green. The transmitted light under such circumstances must pass from yellow through orange to red. This also is exactly what we find in nature. Thus, while the reflected light gives us at noon the deep azure of the Alpine skies, the transmitted light gives us at sunset the warm crimson of the Alpine snows. The phenomena certainly occur *as if* our atmosphere were a medium rendered slightly turbid by the mechanical suspension of exceedingly small foreign particles.

Here, as before, we encounter our sceptical '*as if*.' It is one of the parasites of science, ever at hand, and ready to plant itself and sprout, if it can, on the weak points of our philosophy. But a strong constitution defies the parasite, and in our case, as we question the phenomena, probability grows like growing health, until in the end the malady of doubt is completely extirpated. The first question that naturally arises is this: Can small particles be really proved to act in the manner indicated? No doubt of it. Each one of you can submit the question to an experimental test. Water will not dissolve resin, but spirit will dissolve it; and when spirit holding resin in solution is dropped into water, the resin immediately separates in solid particles, which render the water milky. The coarseness of this precipitate depends on the quantity of the dissolved resin. You can cause it to separate either in thick clots or in exceedingly fine particles. Professor Brücke has given us the proportions which produce particles particularly suited to our present purpose. One gramme of clean mastic is dissolved in eighty-seven grammes of absolute alcohol, and the transparent solution is allowed to drop into a beaker containing clear water, kept briskly stirred. An exceedingly fine precipitate is thus formed, which declares its presence by its action upon light. Placing a dark surface behind the beaker, and permitting the light to fall into it from the top or front, the medium is seen to be distinctly blue. It is not perhaps so perfect a blue as may be seen on exceptional days among the Alps, but it is a very fair sky-blue. A trace of soap in water gives a tint of blue. London, and I fear Liverpool, milk makes an approximation to the same colour, through the operation of the same cause; and Helmholtz has irreverently disclosed the fact that the deepest blue eye is simply a turbid medium.

The action of turbid media upon light was illustrated by Goethe, who, though unacquainted with the undulatory theory, was led by his experiments to regard the firmament as an illuminated turbid medium, with the darkness of space behind it. He describes glasses showing a bright yellow by transmitted, and a beautiful blue by reflected, light. Professor Stokes, who was probably the first to discern the real nature of the action of small particles on the waves of ether,[1] describes a glass of a similar kind.[2] Capital specimens of such glass are to be found at Salviati's, in St. James's Street. What artists call 'chill' is no doubt an effect of this description. Through the action of minute particles, the browns of a picture often present the appearance of the bloom of a plum. By rubbing the varnish with a silk handkerchief optical continuity is established and the chill disappears. Some years ago I witnessed Mr. Hirst experimenting at Zermatt on the turbid water of the Visp. When kept still for a day or so, the grosser matter sank, but the finer particles remained suspended, and gave a distinctly blue tinge to the water. The blueness of certain Alpine lakes has been shown to be in part due to this cause. Professor

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[1] This is inferred from conversation. I am not aware that Professor Stokes has published anything upon the subject.

[2] This glass, by reflected light, had a colour 'strongly resembling that of a decoction of horse-chestnut bark.' Curiously enough, Goethe refers to this very decoction: 'Man nehme einen Streifen frischer Rinde von der Rosskastanie, man stecke denselben in ein Glas Wasser, und in der kürzesten Zeit werden wir das vollkommenste Himmelblau entstehen sehen.'—Goethe's *Werke*, B. xxix. p. 24.

Roscoe has noticed several striking cases of a similar kind. In a very remarkable paper the late Principal Forbes showed that steam issuing from the safety-valve of a locomotive, when favourably observed, exhibits at a certain stage of its condensation the colours of the sky. It is blue by reflected light, and orange or red by transmitted light. The same effect, as pointed out by Goethe, is to some extent exhibited by peat-smoke. More than ten years ago, I amused myself by observing, on a calm day at Killarney, the straight smoke-columns rising from the cabin-chimneys. It was easy to project the lower portion of a column against a dark pine, and its upper portion against a bright cloud. The smoke in the former case was blue, being seen mainly by reflected light; in the latter case it was reddish, being seen mainly by transmitted light. Such smoke was not in exactly the condition to give us the glow of the Alps, but it was a step in this direction. Brücke's fine precipitate above referred to looks yellowish by transmitted light; but, by duly strengthening the precipitate, you may render the white light of noon as ruby-coloured as the sun, when seen through Liverpool smoke, or upon Alpine horizons. I do not, however, point to the gross smoke arising from coal as an illustration of the action of small particles, because such smoke soon absorbs and destroys the waves of blue, instead of sending them to the eyes of the observer.

These multifarious facts, and numberless others which cannot now be referred to, are explained by reference to the single principle, that, where the scattering particles are small in comparison to the ethereal waves, we have in the reflected light a greater proportion of the smaller waves, and in the transmitted light a greater proportion of the larger waves, than existed in the original white light. The consequence, as regards sensation, is that in the one case blue is predominant, and in the other orange or red. Our best microscopes can readily reveal objects not more than $\frac{1}{50000}$th of an inch in diameter. This is less than the length of a wave of red light. Indeed a first-rate microscope would enable us to discern objects not exceeding in diameter the length of the smallest waves of the visible spectrum.[1] By the microscope, therefore, we can test our particles. If they be as large as the light-waves they will infallibly be seen; and if they be not so seen, it is because they are smaller. Some months ago I placed in the hands of our President a liquid containing Brücke's precipitate. The liquid was milky blue, and Mr. Huxley applied to it his highest microscopic power. He satisfied me that had particles of even $\frac{1}{100000}$th of an inch in diameter existed in the liquid, they could not have escaped detection. But no particles were seen. Under the microscope the turbid liquid was not to be distinguished from distilled water.[2]

But we have it in our power to imitate, far more closely than we have hitherto done, the natural conditions of this problem. We can generate, in air, artificial skies, and prove their perfect identity with the natural one, as regards the exhibition of a number of wholly unexpected phenomena. By a continuous process of growth, moreover, we are able to connect sky-matter, if I may use the term, with molecular matter on the one side, and with molar matter, or matter in sensible masses, on the other. In illustration of this, I will take an experiment suggested by some of my own researches, and described by M. Morren of Marseilles at the Exeter meeting of the British Association. Sulphur and oxygen combine to form sulphurous acid gas, two atoms of oxygen and one of sulphur constituting the molecule of sulphurous acid. It has been recently shown that waves of ether issuing from a strong source, such as the sun or the electric light, are competent to shake asunder the atoms of gaseous molecules.[1] A chemist would call this, 'decomposition' by light; but it behoves us, who are examining the power and function of the imagination, to keep constantly before us the physical images which underlie our terms. Therefore I say, sharply and definitely, that the components of the molecules of sulphurous acid are shaken asunder by the ether-waves. Enclosing sulphurous acid in a suitable vessel, placing it in a dark room, and sending through it a powerful beam of light, we at first see nothing: the vessel containing the gas seems as empty as a vacuum. Soon, however, along the track of the beam a beautiful sky-blue colour is observed, which is due to light scattered by the liberated particles of sulphur. For a time the blue grows more intense; it then becomes whitish; and ends in a more or less perfect white. When the action is continued long enough, the tube is filled with a dense cloud of sulphur particles, which by the application of proper means may be rendered individually visible.[2]

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[1] Dallinger and Drysdale have recently measured cilia $\frac{1}{200000}$th of an inch in diameter. 1878.

[2] Like Dr. Burdon Sanderson's 'pyrogen,' the particles of mastic passed, without sensible hindrance, through filtering-paper. By such filtering no freedom from suspended particles is secured. The application of a condensed beam to the filtrate renders this at once evident.

Here, then, our ether-waves untie the bond of chemical affinity, and liberate a body—sulphur—which at ordinary temperatures is a solid, and which therefore soon becomes an object of the senses. We have first of all the free atoms of sulphur, which are incompetent to stir the retina sensibly with scattered light. But these atoms gradually coalesce and form *particles*, which grow larger by continual accretion, until after a minute or two they appear as sky-matter. In this condition they are individually invisible; but collectively they send an amount of wave-motion to the retina, sufficient to produce the firmamental blue. The particles continue, or may be caused to continue, in this condition for a considerable time, during which no microscope can cope with them. But they grow slowly larger, and pass by insensible gradations into the state of *cloud*, when they can no longer elude the armed eye. Thus, without solution of continuity, we start with matter in the atom, and end with matter in the mass; sky-matter being the middle term of the series of transformations.

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[1] See 'New Chemical Reactions produced by Light,' vol. i. p.

[2] M. Morren was mistaken in supposing that a modicum of sulphurous acid, in the drying tubes, had any share in the production of the 'actinic clouds' described by me. A beautiful case of molecular instability in the presence of light is furnished by peroxide of chlorine as proved by Professor Dewar. 1878.

Instead of sulphurous acid, we might choose a dozen other substances, and produce the same effect with all of them. In the case of some—probably in the case of all—it is possible to preserve matter in the firmamental condition for fifteen or twenty minutes under the continual operation of the light. During these fifteen or twenty minutes the particles constantly grow larger, without ever exceeding the size requisite to the production of the celestial blue. Now when two vessels are placed before us, each containing sky-matter, it is possible to state with great distinctness which vessel contains the largest particles. The eye is very sensitive to differences of light, when, as in our experiments, it is placed in comparative darkness, and the wave-motion thrown against the retina is small. The larger particles declare themselves by the greater whiteness of their scattered light. Call now to mind the observation, or effort at observation, made by our President, when he failed to distinguish the particles of mastic in Brücke's medium, and when you have done this, please follow me. A beam of light is permitted to act upon a certain vapour. In two minutes the azure appears, but at the end of fifteen minutes it has not ceased to be azure. After fifteen minutes its colour, and some other phenomena, pronounce it to be a blue of distinctly smaller particles than those sought for in vain by Mr. Huxley. These particles, as already stated, must have been less than $\frac{1}{100000}$th of an inch in diameter. And now I want you to consider the following question: Here are particles which have been growing continually for fifteen minutes, and at the end of that time are demonstrably smaller than those which defied the microscope of Mr. Huxley—*What must have been the size of these particles at the beginning of their growth?* What notion can you form of the magnitude of such particles? The distances of stellar space give us simply a bewildering sense of vastness, without leaving any distinct impression on the mind; and the magnitudes with which we have here to do, bewilder us equally in the opposite direction. We are dealing with infinitesimals, compared with which the test objects of the microscope are literally immense.

Small in mass, the vastness in point of number of the particles of our sky may be inferred from the continuity of its light. It is not in broken patches, nor at scattered points, that the heavenly azure is revealed. To the observer on the summit of Mont Blanc, the blue is as uniform and coherent as if it formed the surface of the most close-grained solid. A marble dome would not exhibit a stricter continuity. And Mr. Glaisher will inform you, that if our hypothetical shell were lifted to twice the height of Mont Blanc above the earth's surface, we should still have the azure overhead. By day this light quenches the stars; even by moonlight it is able to exclude from vision all stars between the fifth and the eleventh magnitude. It may be likened to a noise, and the feebler stellar radiance to a whisper drowned by the noise.

What is the nature of the particles which shed this light? The celebrated De la Rive ascribes the haze of the Alps in fine weather to floating organic germs. Now the possible existence of germs in such profusion has been held up as an absurdity. It has been affirmed that they would darken the air, and on the assumed impossibility of their existence in the requisite numbers, without invasion of the solar light, an apparently powerful argument has been based by believers in spontaneous generation. Similar arguments have been used by the opponents of the germ theory of epidemic disease, who have triumphantly challenged an appeal to the microscope and the chemist's balance to decide the question. Such arguments, however, are founded on a defective acquaintance with the powers and properties of matter. Without committing myself in the least to De la Rive's notion, to the doctrine of spontaneous generation, or to the germ theory of disease, I would simply draw attention to the demonstrable fact, that, in the atmosphere, we have particles which defy both the microscope and the balance, which do not darken the air, and which exist, nevertheless, in multitudes sufficient to reduce to insignificance the Israelitish hyperbole regarding the sands upon the seashore.

The varying judgments of men on these and other questions may perhaps be, to some extent, accounted for by that doctrine of Relativity which plays so important a part in philosophy. This doctrine affirms that the impressions made upon us by any circumstance, or combination of circumstances, depend upon our previous state. Two travellers upon the same height, the one having ascended to it from the plain, the other having descended to it from a higher elevation, will be differently affected by the scene around them. To the one nature is expanding, to the other it is contracting, and impressions which have two such different antecedent states are sure to differ. In our scientific judgments the law of relativity may also play an important part. To two men, one educated in the school of the senses, having mainly occupied himself with observation; the other educated in the school of imagination as well, and exercised in the conceptions of atoms and molecules to which we have so frequently referred, a bit of matter, say $\frac{1}{50000}$th of an inch in diameter, will present itself differently. The one descends to it from his molar heights, the other climbs to it from his molecular lowlands. To the one it appears small, to the other large. So, also, as regards the appreciation of the most minute forms of life revealed by the microscope. To one of the men these naturally appear conterminous with the ultimate particles of matter; there is but a step from the atom to the organism. The other discerns numberless organic gradations between both. Compared with his atoms, the smallest vibrios and bacteria of the microscopic field are as behemoth and leviathan. The law of relativity may to some extent explain the different attitudes of two such persons with regard to the question of spontaneous generation. An amount of evidence which satisfies the one entirely fails to satisfy the other; and while to the one the last bold defence and startling expansion of the doctrine by Dr. Bastian will appear perfectly conclusive, to the other it will present itself as merely imposing a labour of demolition on subsequent investigators.[1]

Let me say here that many of our physiological observers appear to form a very inadequate estimate of the distance which separates the microscopic from the molecular limit, and that, as a consequence, they sometimes employ a phraseology calculated to mislead. When, for example, the contents of a cell are described as perfectly homogeneous or as absolutely structureless, because the microscope fails to discover any structure; or when two structures are pronounced to be without difference, because the microscope can discover none, then, I think the microscope begins to play a mischievous part. A little consideration will make it plain that the microscope can have no voice in the question of germ structure. Distilled water is more perfectly homogeneous than any possible organic germ. What is it that causes the liquid to cease contracting at 39° Fahr., and to expand until it freezes? We have here a structural process of which the microscope can take no note, nor is it likely to do so by any conceivable extension of its powers. Place distilled water in the field of an electro-magnet, and bring a microscope to bear upon it. Will any change be observed when the magnet is excited? Absolutely none; and still profound and complex changes have occurred. First of all, the particles of water have been rendered diamagnetically polar; and secondly, in virtue of the structure impressed upon it by the magnetic whirl of its molecules, the liquid twists a ray of light in a fashion perfectly determinate both as to quantity and direction.

Have the diamond, the amethyst, and the countless other crystals formed in the laboratories of nature and of man no structure? Assuredly they have; but what can the microscope make of it? Nothing. It cannot be too distinctly borne in mind that between the microscopic limit, and the true molecular limit, there is room for infinite permutations and combinations. It is in this region that the poles of the atoms are arranged, that tendency is given to their powers; so that when these poles and powers have free action, proper stimulus, and a suitable environment, they determine, first the germ, and afterwards the complete organism. This first marshalling of the atoms, on which all subsequent action depends, baffles a keener power than that of the microscope. When duly pondered, the complexity of the problem raises the doubt, not of the power of our instrument, for that is *nil*, but whether we ourselves possess the intellectual elements which will ever enable us to grapple with the ultimate structural energies of nature.[1]

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[1] When these words were uttered I did not imagine that the chief labour of demolition would fall upon myself. 1878.

In more senses than one Mr. Darwin has drawn heavily upon the scientific tolerance of his age. He has drawn heavily upon time in his development of species, and he has drawn adventurously upon matter in his theory of pangenesis. According to this theory, a germ, already microscopic, is a world of minor germs. Not only is the organism as a whole wrapped up in the germ, but every organ of the organism has there its special seed. This, I say, is an adventurous draft on the power of matter to divide itself and distribute its forces. But, unless we are perfectly sure that he is overstepping the bounds of reason, that he is unwittingly sinning against observed fact or demonstrated law—for a mind like that of Darwin can never sin wittingly against either fact or law—we ought, I think, to be cautious in limiting his intellectual horizon. If there be the least doubt in the matter, it ought to be given in favour of the freedom of such a mind. To it a vast possibility is in itself a dynamic power, though the possibility may never be drawn upon. It gives me pleasure to think that the facts and reasonings of this discourse tend rather towards the justification of Mr. Darwin, than towards his condemnation; for they seem to show the perfect competence of matter and force, as regards divisibility and distribution, to bear the heaviest strain that he has hitherto imposed upon them.

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[1] 'In using the expression "one sort of living substance" I must guard against being supposed to mean that any kind of living protoplasm is homogeneous. Hyaline though it may appear, we are not at present able to assign any limit to its complexity of structure.'—Burdon Sanderson, in the 'British Medical Journal,' January 16, 1875.

We have here scientific insight, and its correlative caution. In fact Dr. Sanderson's important researches are a continued illustration of the position laid down above.

In the case of Mr. Darwin, observation, imagination, and reason combined have run back with wonderful sagacity and success over a certain length of the line of biological succession. Guided by analogy, in his 'Origin of Species' he placed at the root of life a primordial germ, from which he conceived the amazing variety of the organisms now upon the earth's surface might be deduced. If this hypothesis were even true, it would not be final. The human mind would infallibly look behind the germ, and however hopeless the attempt, would enquire into the history of its genesis. In this dim twilight of conjecture the searcher welcomes every gleam, and seeks to augment his light by indirect incidences. He studies the methods of nature in the ages and the worlds within his reach, in order to shape the course of speculation in antecedent ages and worlds. And though the certainty possessed by experimental enquiry is here shut out, we are not left entirely without guidance. From the examination of the solar system, Kant and Laplace came to the conclusion that its various bodies once formed parts of the same undislocated mass; that matter in a nebulous form preceded matter in its present form; that as the ages rolled away, heat was wasted, condensation followed, planets were detached; and that finally the chief portion of the hot cloud reached, by self-compression, the magnitude and density of our sun. The earth itself offers evidence of a fiery origin; and in our day the hypothesis of Kant and Laplace receives the independent countenance of spectrum analysis, which proves the same substances to be common to the earth and sun.

Accepting some such view of the construction of our system as probable, a desire immediately arises to connect the present life of our planet with the past. We wish to know something of our remotest ancestry. On its first detachment from the central mass, life, as we understand it, could not have been present on the earth. How, then, did it come there? The thing to be encouraged here is a reverent freedom—a freedom preceded by the hard discipline which checks licentiousness in speculation—while the thing to be repressed, both in science and out of it, is dogmatism. And here I am in the hands of the meeting—willing to end, but ready to go on. I have no right to intrude upon you, unasked, the unformed notions which are floating like clouds, or gathering to more solid consistency, in the modern speculative scientific mind. But if you wish me to speak plainly, honestly, and undisputatiously, I am willing to do so. On the present occasion —

You are ordained to call, and I to come.

Well, your answer is given, and I obey your call.

Two or three years ago, in an ancient London College, I listened to a discussion at the end of a lecture by a very remarkable man. Three or four hundred clergymen were present at the lecture. The orator began with the civilisation of Egypt in the time of Joseph; pointing out the very perfect organisation of the kingdom, and the possession of chariots, in one of which Joseph rode, as proving a long antecedent period of civilisation. He then passed on to the mud of the Nile, its rate of augmentation, its present thickness, and the remains of human handiwork found therein: thence to the rocks which bound the Nile valley, and which teem with organic remains. Thus in his own clear way he caused the idea of the world's age to expand itself indefinitely before the minds of his audience, and he contrasted this with the age usually assigned to the world. During his discourse he seemed to be swimming against a stream, he manifestly thought that he was opposing a general conviction. He expected resistance in the subsequent discussion; so did I. But it was all a mistake; there was no adverse current, no opposing conviction, no resistance; merely here and there a half-humorous, but unsuccessful attempt to entangle him in his talk. The meeting agreed with all that had been said regarding the antiquity of the earth and of its life. They had, indeed, known it all long ago, and they rallied the lecturer for coming amongst them with so stale a story. It was quite plain that this large body of clergymen, who were, I should say, to be ranked amongst the finest samples of their class, had entirely given up the ancient landmarks, and transported the conception of life's origin to an indefinitely distant past.

This leads us to the gist of our present enquiry, which is this: Does life belong to what we call matter, or is it an independent principle inserted into matter at some suitable epoch—say when the physical conditions became such as to permit of the development of life? Let us put the question with the reverence due to a faith and culture in which we all were cradled, and which are the undeniable historic antecedents of our present enlightenment. I say, let us put the question reverently, but let us also put it clearly and definitely. There are the strongest grounds for believing that during a certain period of its history the earth was not, nor was it fit to be, the theatre of life. Whether this was ever a nebulous period, or merely a molten period, does not signify much; and if we revert to the nebulous condition, it is because the probabilities are really on its side. Our question is this: Did creative energy pause until the nebulous matter had condensed, until the earth had been detached, until the solar fire had so far withdrawn from the earth's vicinity as to permit a crust to gather round the planet? Did it wait until the air was isolated; until the seas were formed; until evaporation, condensation, and the descent of rain had begun; until the eroding forces of the atmosphere had weathered and decomposed the molten rocks so as to form soils; until the sun's rays had become so tempered by distance, and by waste, as to be chemically fit for the decompositions necessary to vegetable life? Having waited through these æons until the proper conditions had set in, did it send the fiat forth, 'Let there be Life!'? These questions define a hypothesis not without its difficulties, but the dignity of which in relation to the world's knowledge was demonstrated by the nobleness of the men whom it sustained.

Modern scientific thought is called upon to decide between this hypothesis and another; and public thought generally will afterwards be called upon to do the same. But, however the convictions of individuals here and there may be influenced, the process must be slow and secular which commends the hypothesis of

Natural Evolution to the public mind. For what are the core and essence of this hypothesis? Strip it naked, and you stand face to face with the notion that not alone the more ignoble forms of animalcular or animal life, not alone the nobler forms of the horse and lion, not alone the exquisite and wonderful mechanism of the human body, but that the human mind itself—emotion, intellect, will, and all their phenomena—were once latent in a fiery cloud. Surely the mere statement of such a notion is more than a refutation. But the hypothesis would probably go even farther than this. Many who hold it would probably assent to the position that, at the present moment, all our philosophy, all our poetry, all our science, and all our art—Plato, Shakspeare, Newton, and Raphael—are potential in the fires of the sun. We long to learn something of our origin. If the Evolution hypothesis be correct, even this unsatisfied yearning must have come to us across the ages which separate the primeval mist from the consciousness of to-day. I do not think that any holder of the Evolution hypothesis would say that I overstate or overstrain it in any way. I merely strip it of all vagueness, and bring before you, unclothed and unvarnished, the notions by which it must stand or fall.

Surely these notions represent an absurdity too monstrous to be entertained by any sane mind. But why are such notions absurd, and why should sanity reject them? The law of Relativity, of which we have previously spoken, may find its application here. These Evolution notions are absurd, monstrous, and fit only for the intellectual gibbet, in relation to the ideas concerning matter which were drilled into us when young. Spirit and matter have ever been presented to us in the rudest contrast, the one as all-noble, the other as all-vile. But is this correct? Upon the answer to this question all depends. Supposing that, instead of having the foregoing antithesis of spirit and matter presented to our youthful minds, we had been taught to regard them as equally worthy, and equally wonderful; to consider them, in fact, as two opposite faces of the self-same mystery. Supposing that in youth we had been impregnated with the notion of the poet Goethe, instead of the notion of the poet Young, and taught to look upon matter, not as 'brute matter,' but as the 'living garment of God;' do you not think that under these altered circumstances the law of Relativity might have had an outcome different from its present one? Is it not probable that our repugnance to the idea of primeval union between spirit and matter might be considerably abated? Without this total revolution of the notions now prevalent, the Evolution hypothesis must stand condemned; but in many profoundly thoughtful minds such a revolution has already taken place. They degrade neither member of the mysterious duality referred to; but they exalt one of them from its abasement, and repeal the divorce hitherto existing between them. In substance, if not in words, their position as regards the relation of spirit and matter is: 'What God hath joined together, let not man put asunder.'

You have been thus led to the outer rim of speculative science, for beyond the nebulæ scientific thought has never hitherto ventured. I have tried to state that which I considered ought, in fairness, to be outspoken. I neither think this Evolution hypothesis is to be flouted away contemptuously, nor that it ought to be denounced as wicked. It is to be brought before the bar of disciplined reason, and there justified or condemned. Let us hearken to those who wisely support it, and to those who wisely oppose it; and let us tolerate those, whose name is legion, who try foolishly to do either of these things. The only thing out of place in the discussion is dogmatism on either side. Fear not the Evolution hypothesis. Steady yourselves, in its presence, upon that faith in the ultimate triumph of truth which was expressed by old Gamaliel when he said: 'If it be of God, ye cannot overthrow it; if it be of man, it will come to nought.' Under the fierce light of scientific enquiry, it is sure to be dissipated if it possess not a core of truth. Trust me, its existence as a hypothesis is quite compatible with the simultaneous existence of all those virtues to which the term 'Christian' has been applied. It does not solve—it does not profess to solve—the ultimate mystery of this universe. It leaves, in fact, that mystery untouched. For, granting the nebula and its potential life, the question, whence they came, would still remain to baffle and bewilder us. At bottom, the hypothesis does nothing more than 'transport the conception of life's origin to an indefinitely distant past.'

Those who hold the doctrine of Evolution are by no means ignorant of the uncertainty of their data, and they only yield to it a provisional assent. They regard the nebular hypothesis as probable, and, in the utter absence of any evidence to prove the act illegal, they extend the method of nature from the present into the past. Here the observed uniformity of nature is their only guide. Within the long range of physical enquiry, they have never discerned in nature the insertion of caprice. Throughout this range, the laws of physical and intellectual continuity have run side by side. Having thus determined the elements of their curve in a world of observation and experiment, they prolong that curve into an antecedent world, and accept as probable the unbroken sequence of development from the nebula to the present time. You never hear the really philosophical defenders of the doctrine of Uniformity speaking of *impossibilities* in nature. They never say, what they are constantly charged with saying, that it is impossible for the Builder of the universe to alter His work. Their business is not with the possible, but the actual—not with a world which *might* be, but with a world that *is*. This they explore with a courage not unmixed with reverence, and according to methods which, like the quality of a tree, are tested by their fruits. They have but one desire —to know the truth. They have but one fear—to believe a lie. And if they know the strength of science, and rely upon it with unswerving trust, they also know the limits beyond which science ceases to be strong. They best know that questions offer themselves to thought, which science, as now prosecuted, has not even the tendency to solve. They have as little fellowship with the atheist who says there is no God, as with the theist who professes to know the mind of God. 'Two things,' said Immanuel Kant, 'fill me with awe: the starry heavens, and the sense of moral responsibility in man.' And in his hours of health and strength and sanity, when the stroke of action has ceased, and the pause of reflection has set in, the scientific investigator finds himself overshadowed by the same awe. Breaking contact with the hampering details of earth, it associates him with a Power which gives fulness and tone to his existence, but which he can neither analyse nor comprehend.

There is one God supreme over all gods, diviner than mortals,
Whose form is not like unto man's, and as unlike his nature;
But vain mortals imagine that gods like themselves are begotten,
With human sensations and voice and corporeal members;
So, if oxen or lions had hands and could work in man's fashion,
And trace out with chisel or brush their conception of Godhead,
Then would horses depict gods like horses, and oxen like oxen,
Each kind the divine with its own form and nature endowing.

XENOPHANES of COLOPHON (six centuries B.C.),
Supernatural Religion, vol. i. p. 76.

IX.

THE BELFAST ADDRESS.[1]

§ 1.

AN impulse inherent in primeval man turned his thoughts and questionings betimes towards the sources of natural phenomena. The same impulse, inherited and intensified, is the spur of scientific action to-day. Determined by it, by a process of abstraction from experience we form physical theories which lie beyond the pale of experience, but which satisfy the desire of the mind to see every natural occurrence resting upon a cause. In forming their notions of the origin of things, our earliest historic (and doubtless, we might add, our prehistoric) ancestors pursued, as far as their intelligence permitted, the same course. They also fell back upon experience; but with this difference—that the particular experiences which furnished the warp and woof of their theories were drawn, not from the study of nature, but from what lay much closer to them—the observation of men. Their theories accordingly took an anthropomorphic form. To supersensual beings, which, 'however potent and invisible, were nothing but a species of human creatures, perhaps raised from among mankind, and retaining all human passions and appetites,'[1] were handed over the rule and governance of natural phenomena.

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[1] Delivered before the British Association on Wednesday evening, August 19, 1874.

Tested by observation and reflection, these early notions failed in the long run to satisfy the more penetrating intellects of our race. Far in the depths of history we find men of exceptional power differentiating themselves from the crowd, rejecting these anthropomorphic notions, and seeking to connect natural phenomena with their physical principles. But, long prior to these purer efforts of the understanding, the merchant had been abroad, and rendered the philosopher possible; commerce had been developed, wealth amassed, leisure for travel and speculation secured, while races educated under different conditions, and therefore differently informed and endowed, had been stimulated and sharpened by mutual contact. In those regions where the commercial aristocracy of ancient Greece mingled with their eastern neighbours, the sciences were born, being nurtured and developed by free-thinking and courageous men. The state of things to be displaced may be gathered from a passage of Euripides quoted by Hume. 'There is nothing in the world; no glory, no prosperity. The gods toss all into confusion; mix everything with its reverse, that all of us, from our ignorance and uncertainty, may pay them the more worship and reverence.' Now as science demands the radical extirpation of caprice, and the absolute reliance upon law in nature, there grew, with the growth of scientific notions, a desire and determination to sweep from the field of theory this mob of gods and demons, and to place natural phenomena on a basis more congruent with themselves.

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[1] Hume, 'Natural History of Religion.'

The problem which had been previously approached from above, was now attacked from below; theoretic effort passed from the super- to the sub-sensible. It was felt that to construct the universe in idea, it was necessary to have some notion of its constituent parts —of what Lucretius subsequently called the 'First Beginnings.' Abstracting again from experience, the leaders of scientific speculation reached at length the pregnant doctrine of atoms and molecules, the latest developments of which were set forth with such power and clearness at the last meeting of the British Association. Thought, no doubt, had long hovered about this doctrine before it attained the precision and completeness which it assumed in the mind of Democritus,[1] a philosopher who may well for a moment arrest our attention. 'Few great men,' says Lange, a non-materialist, in his excellent 'History of Materialism,' to the spirit and to the letter of which I am equally indebted, 'have been so despitefully used by history as Democritus. In the distorted images sent down to us through unscientific traditions, there remains of him almost nothing but the name of "the laughing philosopher," while figures of immeasurably smaller significance spread themselves out at full length before us.' Lange speaks of Bacon's high appreciation of Democritus—for ample illustrations of which I am indebted to my excellent friend Mr. Spedding, the learned editor and biographer of Bacon. It is evident, indeed, that Bacon considered

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[1] Born 460 B.C.

Democritus to be a man of weightier metal than either Plato or Aristotle, though their philosophy 'was noised and celebrated in the schools, amid the din and pomp of professors.' It was not they, but Genseric and Attila and the barbarians, who destroyed the atomic philosophy. 'For, at a time when all human learning had suffered shipwreck, these planks of Aristotelian and Platonic philosophy, as being of a lighter and more inflated substance, were preserved and came down to us, while things more solid sank and almost passed into oblivion.'

The son of a wealthy father, Democritus devoted the whole of his inherited fortune to the culture of his mind. He travelled everywhere; visited Athens when Socrates and Plato were there, but quitted the city without making himself known. Indeed, the dialectic strife in which Socrates so much delighted, had no charm for Democritus, who held that 'the man who readily contradicts, and uses many words, is unfit to learn anything truly right.' He is said to have discovered and educated Protagoras the Sophist, being struck as much by the manner in which he, being a hewer of wood, tied up his faggots, as by the sagacity of his conversation. Democritus returned poor from his travels, was supported by his brother, and at length wrote his great work entitled 'Diakosmos,' which he read publicly before the people of his native town. He was honoured by his countrymen in various ways, and died serenely at a great age.

The principles enunciated by Democritus reveal his uncompromising antagonism to those who deduced the phenomena of nature from the caprices of the gods. They are briefly these: 1. From nothing comes nothing. Nothing that exists can be destroyed. All changes are due to the combination and separation of molecules.

2. Nothing happens by chance; every occurrence has its cause, from which it follows by necessity. 3. The only existing things are the atoms and empty space; all else is mere opinion. 4. The atoms are infinite in number and infinitely various in form; they strike together, and the lateral motions and whirlings which thus arise are the beginnings of worlds. 5. The varieties of all things depend upon the varieties of their atoms, in number, size, and aggregation. 6. The soul consists of fine, smooth, round atoms, like those of fire. These are the most mobile of all: they interpenetrate the whole body, and in their motions the phenomena of life arise.

The first five propositions are a fair general statement of the atomic philosophy, as now held. As regards the sixth, Democritus made his finer atoms do duty for the nervous system, whose functions were then unknown. The atoms of Democritus are individually without sensation; they combine in obedience to mechanical laws; and not only organic forms, but the phenomena of sensation and thought, are the result of their combination.

That great enigma, 'the exquisite adaptation of one part of an organism to another part, and to the conditions of life,' more especially the construction of the human body, Democritus made no attempt to solve. Empedocles, a man of more fiery and poetic nature, introduced the notion of love and hate among the atoms, to account for their combination and separation; and bolder than Democritus, he struck in with the penetrating thought, linked, however, with some wild speculation, that it lay in the very nature of those combinations which were suited to their ends (in other words, in harmony with their environment) to maintain themselves, while unfit combinations, having no proper habitat, must rapidly disappear. Thus, more than 2,000 years ago, the doctrine of the 'survival of the fittest,' which in our day, not on the basis of vague conjecture, but of positive knowledge, has been raised to such extraordinary significance, had received at all events partial enunciation.[1]

Epicurus,[2] said to be the son of a poor schoolmaster at Samos, is the next dominant figure in the history of the atomic philosophy. He mastered the writings of Democritus, heard lectures in Athens, went back to Samos, and subsequently wandered through various countries. He finally returned to Athens, where he bought a garden, and surrounded himself by pupils, in the midst of whom he lived a pure and serene life, and died a peaceful death. Democritus looked to the soul as the ennobling part of man; even beauty, without understanding, partook of animalism. Epicurus also rated the spirit above the body; the pleasure of the body being that of the moment, while the spirit could draw upon the future and the past. His philosophy was almost identical with that of Democritus, but he never quoted either friend or foe. One main object of Epicurus was to free the world from superstition and the fear of death. Death he treated with indifference. It merely robs us of sensation. As long as we are, death is not; and when death is, we are not. Life has no more evil for him who has made up his mind that it is no evil not to live. He adored the gods, but not in the ordinary fashion. The idea of Divine power, properly purified, he thought an elevating one. Still he taught, 'Not he is godless who rejects the gods of the crowd, but rather he who accepts them.' The gods were to him eternal and immortal beings, whose blessedness excluded every thought of care or occupation of any kind. Nature pursues her course in accordance with everlasting laws, the gods never interfering. They haunt

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[1] See 'Lange,' 2nd edit., p. 23.

[2] Born 342 B.C.

> The lucid interspace of world and world
> Where never creeps a cloud or moves a wind,
> Nor ever falls the least white star of snow,
> Nor ever lowest roll of thunder moans,
> Nor sound of human sorrow mounts to mar
> Their sacred everlasting calm.[1]

Lange considers the relation of Epicurus to the gods subjective; the indication, probably, of an ethical requirement of his own nature. We cannot read history with open eyes, or study human nature to its depths, and fail to discern such a requirement. Man never has been, and he never will be, satisfied with the operations and products of the Understanding alone; hence physical science cannot cover all the demands of his nature. But the history of the efforts made to satisfy these demands might be broadly described as a history of errors—the error, in great part, consisting in ascribing fixity to that which is fluent, which varies as we vary, being gross when we are gross, and becoming, as our capacities widen, more abstract and sublime. On one great point the mind of Epicurus was at peace. He neither sought nor expected, here or hereafter, any personal profit from his relation to the gods. And it is assuredly a fact, that loftiness and serenity of thought may be promoted by conceptions which involve no idea of profit of this kind. 'Did I not believe,' said a great man[2] to me once, 'that an Intelligence is at the heart of things, my life on earth would be intolerable.' The utterer of these words is not, in my opinion, rendered less but more noble by the fact, that it was the need of ethical harmony here, and not the thought of personal happiness hereafter, that prompted his observation.

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[1] Tennyson's 'Lucretius.'

[2] Carlyle.

There are persons, not belonging to the highest intellectual zone, nor yet to the lowest, to whom perfect clearness of exposition suggests want of depth. They find comfort and edification in an abstract and learned phraseology. To such people Epicurus, who spared no pains to rid his style of every trace of haze and turbidity, appeared, on this very account, superficial. He had, however, a disciple who thought it no unworthy occupation to spend his days and nights in the effort to reach the clearness of his master, and to whom the Greek philosopher is mainly indebted for the extension and perpetuation of his fame. Some two centuries after the death of Epicurus, Lucretius[1] wrote his great poem, 'On the Nature of Things,' in which he, a Roman, developed with extraordinary ardour the philosophy of his Greek predecessor. He wishes to win over his friend Memnius to the school of Epicurus; and although he has no rewards in a future life to offer, although his object appears to be a purely negative one, he addresses his friend with the heat of an apostle. His object, like that of his great forerunner, is the destruction of superstition; and considering that men in his day trembled before every natural event as a direct monition from the gods, and that everlasting torture was also in prospect, the freedom aimed at by Lucretius might be deemed a positive good. 'This terror,' he says, 'and darkness of mind, must be dispelled, not by the rays of the sun and glittering shafts of day, but by the aspect and the law of nature.' He refutes the notion that anything can come out of nothing, or that what is once begotten can be recalled to nothing. The first beginnings, the atoms, are indestructible, and into them all things can be resolved at last. Bodies are partly atoms and partly combinations of atoms; but the atoms nothing can quench. They are strong in solid singleness, and, by their denser combination, all things can be closely packed and exhibit enduring strength. He denies that matter is infinitely divisible. We come at length to the atoms, without which, as an imperishable substratum, all order in the generation and development of things would be destroyed.

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[1] Born 99 B.C.

The mechanical shock of the atoms being, in his view, the all-sufficient cause of things, he combats the notion that the constitution of nature has been in any way determined by intelligent design. The interaction of the atoms throughout infinite time rendered all manner of combinations possible. Of these, the fit ones persisted, while the unfit ones disappeared. Not after sage deliberation did the atoms station themselves in their right places, nor did they bargain what motions they should assume. From all eternity they have been driven together, and, after trying motions and unions of every kind, they fell at length into the arrangements out of which this system of things has been evolved. 'If you will apprehend and keep in mind these things, Nature, free at once, and rid of her haughty lords, is seen to do all things spontaneously of herself, without the meddling of the gods.'[1]

To meet the objection that his atoms cannot be seen, Lucretius describes a violent storm, and shows that the invisible particles of air act in the same way as the visible particles of water. We perceive, moreover, the different smells of things, yet never see them coming to our nostrils. Again, clothes hung up on a shore which waves break upon, become moist, and then get dry if spread out in the sun, though no eye can see either the approach or the escape of the water-particles. A ring, worn long on the finger, becomes thinner; a water-drop hollows out a stone; the ploughshare is rubbed away in the field; the street-pavement is worn by the feet; but the particles that disappear at any moment we cannot see. Nature acts through invisible particles. That Lucretius had a strong scientific imagination the foregoing references prove. A fine illustration of his power in this respect, is his explanation of the apparent rest of bodies whose atoms are in motion. He employs the image of a flock of sheep with skipping lambs, which, seen from a distance, presents simply a white patch upon the green hill, the jumping of the individual lambs being quite invisible.

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[1] Monro's translation. In his criticism of this work ('Contemporary Review,' 1867) Dr. Hayman does not appear to be aware of the really sound and subtile observations on which the reasoning of Lucretius, though erroneous, sometimes rests.

His vaguely grand conception of the atoms falling eternally through space, suggested the nebular hypothesis to Kant, its first propounder. Far beyond the limits of our visible world are to be found atoms innumerable, which have never been united to form bodies, or which, if once united, have been again dispersed—falling silently through immeasurable intervals of time and space. As everywhere throughout the All the same conditions are repeated, so must the phenomena be repeated also. Above us, below us, beside us, therefore, are worlds without end; and this, when considered, must dissipate every thought of a deflection of the universe by the gods. The worlds come and go, attracting new atoms out of limitless space, or dispersing their own particles. The reputed death of Lucretius, which forms the basis of Mr. Tennyson's noble poem, is in strict accordance with his philosophy, which was severe and pure.

§ 2.

Still earlier than these three philosophers, and during the centuries between the first of them and the last, the human intellect was active in other fields than theirs. Pythagoras had founded a school of mathematics, and made his experiments on the harmonic intervals. The Sophists had run through their career. At Athens had appeared Socrates, Plato, and Aristotle, who ruined the Sophists, and whose yoke remains to some extent unbroken to the present hour. Within this period also the School of Alexandria was founded, Euclid wrote his 'Elements' and made some advance in optics. Archimedes had propounded the theory of the lever, and the principles of hydrostatics. Astronomy was immensely enriched by the discoveries of Hipparchus, who was followed by the historically more celebrated Ptolemy. Anatomy had been made the basis of scientific medicine; and it is said by Draper [1] that vivisection had begun. In fact, the science of ancient Greece had already cleared the world of the fantastic images of divinities operating capriciously through natural phenomena. It had shaken itself free from that fruitless scrutiny 'by the internal light of the mind alone,' which had vainly sought to transcend experience, and to reach a knowledge of ultimate causes. Instead of accidental observation, it had introduced observation with a purpose; instruments were employed to aid the senses; and scientific method was rendered in a great measure complete by the union of Induction and Experiment.

What, then, stopped its victorious advance? Why was the scientific intellect compelled, like an exhausted soil, to lie fallow for nearly two millenniums, before it could regather the elements necessary to its fertility and strength? Bacon has already let us know one cause; Whewell ascribes this stationary period to four causes—obscurity of thought, servility, intolerance of disposition, enthusiasm of temper; and he gives striking examples of each.[1] But these characteristics must have had their antecedents in the circumstances of the time. Rome, and the other cities of the Empire, had fallen into moral putrefaction. Christianity had appeared, offering the Gospel to the poor, add by moderation, if not asceticism of life, practically protesting against the profligacy of the age. The sufferings of the early Christians, and the extraordinary exaltation of mind which enabled them to triumph over the diabolical tortures to which they were subjected,[2] must have left traces not easily effaced. They scorned the earth, in view of that 'building of God, that house not made with hands, eternal in the heavens.' The Scriptures which ministered to their spiritual needs were also the measure of their Science. When, for example, the celebrated question of Antipodes came to be discussed, the Bible was with many the ultimate court of appeal. Augustine, who flourished A.D. 400, would not deny the rotundity of the earth; but he would deny the possible existence of inhabitants at the other side, 'because no such race is recorded in Scripture among the descendants of Adam.' Archbishop Boniface was shocked at the assumption of a 'world of human beings out of the reach of the means of salvation.' Thus reined in, Science was not likely to make much progress. Later on, the political and theological strife between the Church and civil governments, so powerfully depicted by Draper, must have done much to stifle investigation.

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[1] 'History of the Intellectual Development of Europe,' p. 295.

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[1] 'History of the Inductive Sciences,' vol. i.

[2] Described with terrible vividness in Renan's 'Antichrist.'

Whewell makes many wise and brave remarks regarding the spirit of the Middle Ages. It was a menial spirit. The seekers after natural knowledge had forsaken the fountain of living waters, the direct appeal to nature by observation and experiment, and given themselves up to the remanipulation of the notions of their predecessors. It was a time when thought had become abject, and when the acceptance of mere authority led, as it always does in science, to intellectual death. Natural events, instead of being traced to physical, were referred to moral, causes; while an exercies of the phantasy, almost as degrading as the spiritualism of the present day, took the place of scientific speculation. Then came the mysticism of the Middle Ages, Magic, Alchemy, the Neoplatonic philosophy, with its visionary though sublime abstractions, which caused men to look with shame upon their own bodies, as hindrances to the absorption of the creature in the blessedness of the Creator. Finally came the scholastic philosophy, a fusion, according to Lange, of the least mature notions of Aristotle with the Christianity of the West. Intellectual immobility was the result. As a traveller without a compass in a fog may wander long, imagining he is making way, and find himself after hours of toil at his starting-point, so the schoolmen, having 'tied and untied the same knots, and formed and dissipated the same clouds,'[1] found themselves at the end of centuries in their old position.

With regard to the influence wielded by Aristotle in the Middle Ages, and which, to a less extent, he still wields, I would ask permission to make one remark.

[1] Whewell.

When the human mind has achieved greatness and given evidence of extraordinary power in one domain, there is a tendency to credit it with similar power in all other domains. Thus theologians have found comfort and assurance in the thought that Newton dealt with the question of revelation—forgetful of the fact that the very devotion of his powers, through all the best years of his life, to a totally different class of ideas, not to speak of any natural disqualification, tended to render him less, instead of more competent to deal with theological and historic questions. Goethe, starting from his established greatness as a poet, and indeed from his positive discoveries in Natural History, produced a profound impression among the painters of Germany, when he published his 'Farbenlehre,' in which he endeavoured to overthrow Newton's theory of colours. This theory he deemed so obviously absurd, that he considered its author a charlatan, and attacked him with a corresponding vehemence of language. In the domain of Natural History, Goethe had made really considerable discoveries; and we have high authority for assuming that, had he devoted himself wholly to that side of science, he might have reached an eminence comparable with that which he attained as a poet. In sharpness of observation, in the detection of analogies apparently remote, in the classification and organisation of facts according to the analogies discerned, Goethe possessed extraordinary powers. These elements of scientific enquiry fall in with the disciplines of the poet. But, on the other hand, a mind thus richly endowed in the direction of natural history, may be almost shorn of endowment as regards the physicial and mechanical sciences. Goethe was in this condition. He could not formulate distinct mechanical conceptions; he could not see the force of mechanical reasoning; and, in regions where such reasoning reigns supreme, he became a mere *ignis fatuus* to those who followed him.

I have sometimes permitted myself to compare Aristotle with Goethe—to credit the Stagirite with an almost superhuman power of amassing and systematising facts, but to consider him fatally defective on that side of the mind, in respect to which incompleteness has been just ascribed to Goethe. Whewell refers the errors of Aristotle not to a neglect of facts, but to 'a neglect of the idea appropriate to the facts; the idea of Mechanical cause, which is Force, and the substitution of vague or inapplicable notions, involving only relations of space or emotions of wonder.' This is doubtless true; but the word 'neglect' implies mere intellectual misdirection, whereas in Aristotle, as in Goethe, it was not, I believe, misdirection, but sheer natural incapacity which lay at the root of his mistakes. As a physicist, Aristotle displayed what we should consider some of the worst of attributes in a modern physical investigator—indistinctness of ideas, confusion of mind, and a confident use of language which led to the delusive notion that he had really mastered his subject, while he had, as yet, failed to grasp even the elements of it. He put words in the place of things, subject in the place of object. He preached Induction without practising it, inverting the true order of enquiry, by passing from the general to the particular, instead of from the particular to the general. He made of the universe a closed sphere, in the centre of which he fixed the earth, proving from general principles, to his own satisfaction and to that of the world for near 2,000 years, that no other universe was possible. His notions of motion were entirely unphysical. It was natural or unnatural, better or worse, calm or violent—no real mechanical conception regarding it lying at the bottom of his mind.

He affirmed that a vacuum could not exist, and proved that if it did motion in it would be impossible. He determined *à priori* how many species of animals must exist, and showed on general principles why animals must have such and such parts. When an eminent contemporary philosopher, who is far removed from errors of this kind, remembers these abuses of the *à priori* method, he will be able to make allowance for the jealousy of physicists as to the acceptance of so-called *à priori* truths. Aristotle's errors of detail, as shown by Eucken and Lange, were grave and numerous. He affirmed that only in man we had the beating of the heart, that the left side of the body was colder than the right, that men have more teeth than women, and that there is an empty space at the back of every man's head.

There is one essential quality in physical conceptions, which was entirely wanting in those of Aristotle and his followers—a capability of being placed as coherent pictures before the mind. The Germans express the act of picturing by the word *vorstellen*, and the picture they call a *Vorstellung*. We have no word in English which comes nearer to our requirements than *Imagination*; and, taken with its proper limitations, the word answers very well. But it is tainted by its associations, and therefore objectionable to some minds. Compare, with reference to this capacity of mental presentation, the case of the Aristotelian, who refers the ascent of water in a pump to Nature's abhorrence of a vacuum, with that of Pascal when he proposed to solve the question of atmospheric pressure by the ascent of the Puy de Dôme. In the one case the terms of the explanation refuse to fall into place as a physical image; in the other the image is distinct, the descent and rise of the barometer being clearly figured beforehand as the balancing of two varying and opposing pressures.

§ 3.

During the drought of the Middle Ages in Christendom, the Arabian intellect, as forcibly shown by Draper, was active. With the intrusion of the Moors into Spain, order, learning, and refinement took the place of their opposites. When smitten with disease, the Christian peasant resorted to a shrine, the Moorish one to an instructed physician. The Arabs encouraged translations from the Greek philosophers, but not from the Greek poets. They turned in disgust 'from the lewdness of our classical mythology, and denounced as an unpardonable blasphemy all connection between the impure Olympian Jove and the Most High God.' Draper traces still farther than Whewell the Arab elements in our scientific terms. He gives examples of what Arabian men of science accomplished, dwelling particularly on Alhazen, who was the first to correct the Platonic notion that rays of light are emitted by the eye. Alhazen discovered atmospheric refraction, and showed that we see the sun and the moon after they have set. He explained the enlargement of the sun and moon, and the shortening of the vertical diameters of both these bodies when near the horizon. He was aware that the atmosphere decreases in density with increase of elevation, and actually fixed its height at 58½ miles. In the 'Book of the Balance of Wisdom,' he sets forth the connection between the weight of the atmosphere and its increasing density. He shows that a body will weigh differently in a rare and dense atmosphere, and he considers the force with which plunged bodies rise through heavier media. He understood the doctrine of the centre of gravity, and applied it to the investigation of balances and steelyards. He recognised gravity as a force, though he fell into the error of it is said that the old man received a copy of it a few days before his death, and then departed in peace.

The Italian philosopher, Giordano Bruno, was one of the earliest converts to the new astronomy. Taking Lucretius as his exemplar, he revived the notion of the infinity of worlds; and, combining with it the doctrine of Copernicus, reached the sublime generalisation that the fixed stars are suns, scattered numberless through space, and accompanied by satellites, which bear the same relation to them that our earth does to our sun, or our moon to our earth. This was an expansion of transcendent import; but Bruno came closer than this to our present line of thought. Struck with the problem of the generation and maintenance of organisms, and duly pondering it, he came to the conclusion that Nature, in her productions, does not imitate the technic of man. Her process is one of unravelling and unfolding. The infinity of forms under which matter appears was not imposed upon it by an external artificer; by its own intrinsic force and virtue it brings these forms forth. Matter is not the mere naked, empty *capacity* which philosophers have pictured her to be, but the universal mother, who brings forth all things as the fruit of her own womb.

This outspoken man was originally a Dominican monk. He was accused of heresy and had to fly, seeking refuge in Geneva, Paris, England, and Germany. In 1592 he fell into the hands of the Inquisition at Venice. He was imprisoned for many years, tried, degraded, excommunicated, and handed over to the Civil power, with the request that he should be treated gently, and 'without the shedding of blood.' This meant that he was to be burnt; and burnt accordingly he was, on February 16, 1600. To escape a similar fate Galileo, thirty-three years afterwards, abjured upon his knees, with his hands upon the holy Gospels, the heliocentric doctrine, which he knew to be true. After Galileo came Kepler, who from his German home defied the ultramontane power. He traced out from pre-existing observations the laws of planetary motion. Materials were thus prepared for Newton, who bound those empirical laws together by the principle of gravitation.

§ 4.

In the seventeenth century Bacon and Descartes, the restorers of philosophy, appeared in succession. Differently educated and endowed, their philosophic tendencies were different. Bacon held fast to Induction, believing firmly in the existence of an external world, and making collected experiences the basis of all knowledge. The mathematical studies of Descartes gave him a bias towards Deduction; and his fundamental principle was much the same as that of Protagoras, who made the individual man the measure of all things. 'I think, therefore I am,' said Descartes. Only his own identity was sure to him; and the full development of this system would have led to an idealism, in which the outer world would have been resolved into a mere phenomenon of consciousness. Gassendi, one of Descartes's contemporaries, of whom we shall hear more presently, quickly pointed out that the fact of personal existence would be proved as well by reference to any other act, as to the act of thinking. I eat, therefore I am, or I love, therefore I am, would be quite as conclusive. Lichtenberg, indeed, showed that the very thing to be proved was inevitably postulated in the first two words, 'I think;' and it is plain that no inference from the postulate could, by any possibility, be stronger than the postulate itself.

But Descartes deviated strangely from the idealism implied in his fundamental principle. He was the first to reduce, in a manner eminently capable of bearing the test of mental presentation, vital phenomena to purely mechanical principles. Through fear or love, Descartes was a good churchman; he accordingly rejected the notion of an atom, because it was absurd to suppose that God, if He so pleased, could not divide an atom; he puts in the place of the atoms small round particles, and light splinters, out of which he builds the organism. He sketches with marvellous physical insight a machine, with water for its motive power, which shall illustrate vital actions. He has made clear to his mind that such a machine would be competent to carry on the processes of digestion, nutrition, growth, respiration, and the beating of the heart. It would be competent to accept impressions from the external sense, to store them up in imagination and memory, to go through the internal movements of the appetites and passions, and the external movements of the limbs. He deduces these functions of his machine from the mere arrangements of its organs, as the movement of a clock, or other automaton, is deduced from its weights and wheels. 'As far as these functions are concerned,' he says, 'it is not necessary to conceive any other vegetative or sensitive soul, nor any other principle of motion or of life, than the blood and the spirits agitated by the fire which burns continually in the heart, and which is in nowise different from the fires existing in inanimate bodies.' Had Descartes been acquainted with the steam-engine, he would have taken it, instead of a fall of water, as his motive power. He would have shown the perfect analogy which exists between the oxidation of the food in the body, and that of the coal in the furnace. He would assuredly have anticipated Mayer in calling the blood which the heart diffuses, 'the oil of the lamp of life,' deducing all animal motions from the combustion of this oil, as the motions of a steam-engine are deduced from the combustion of its coal. As the matter stands, however, and considering the circumstances of the time, the boldness, clearness, and precision, with which Descartes grasped the problem of vital dynamics constitute a marvellous illustration of intellectual power.[1]

During the Middle Ages the doctrine of atoms had to all appearance vanished from discussion. It probably held its ground among sober-minded and thoughtful men, though neither the church nor the world was prepared to hear of it with tolerance. Once, in the year 1348, it received distinct expression. But retractation by compulsion immediately followed; and, thus discouraged, it slumbered till the seventeenth century, when it was revived by a contemporary and friend of Hobbes of Malmesbury, the orthodox Catholic provost of Digne, Gassendi. But, before stating his relation to the Epicurean doctrine, it will be well to say a few words on the effect, as regards science, of the general introduction of monotheism among European nations.

'Were men,' says Hume, 'led into the apprehension of invisible intelligent power by contemplation of the works of Nature, they could never possibly entertain any conception but of one single Being, who bestowed existence and order on this vast machine, and adjusted all its parts to one regular system.' Referring to the condition of the heathen, who sees a god behind every natural event, thus peopling the world with thousands of beings whose caprices are incalculable, Lange shows the impossibility of any compromise between such notions and those of science, which proceeds on the assumption of never-changing law and causality. 'But,' he continues, with characteristic penetration, 'when the great thought of one God, acting as a unit upon the universe, has been seized, the connection of things in accordance with the law of cause and effect is not only thinkable, but it is a necessary consequence of the assumption. For when I see ten thousand wheels in motion, and know, or believe, that they are all driven by one motive power, then I know that I have before me a mechanism, the action of every part of which is determined by the plan of the whole. So much being assumed, it follows that I may investigate the structure of that machine, and the various motions of its parts. For the time being, therefore, this conception renders scientific action free.' In other words, were a capricious God at the circumference of every wheel and at the end of every lever, the action of the machine would be incalculable by the methods of science. But the actions of all its parts being rigidly determined by their connections and relations, and these being brought into play by a single motive power, then though this last prime mover may elude me, I am still able to comprehend the machinery which it sets in motion. We have here a conception of the relation of Nature to its Author, which seems perfectly acceptable to some minds, but perfectly intolerable to others. Newton and Boyle lived and worked happily under the influence of this conception; Goethe rejected it with vehemence, and the same repugnance to accepting it is manifest in Carlyle.[1]

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[1] See Huxley's admirable 'Essay on Descartes.' 'Lay Sermons,' pp. 364, 365.

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[1] Boyle's model of the universe was the Strasburg clock with an outside Artificer. Goethe, on the other hand, sang—

'Ihm ziemt's die Welt im Innern zu bewegen,
Natur in sich, sich in Natur zu hegen.'

See also Carlyle, 'Past and Present,' chap. v.

The analytic and synthetic tendencies of the human mind are traceable throughout history, great writers ranging themselves sometimes on the one side, sometimes on the other. Men of warm feelings, and minds open to the elevating impressions produced by nature as a whole, whose satisfaction, therefore, is rather ethical than logical, lean to the synthetic side; while the analytic harmonises best with the more precise and more mechanical bias which seeks the satisfaction of the understanding. Some form of pantheism was usually adopted by the one, while a detached Creator, working more or less after the manner of men, was often assumed by the other. Gassendi, as sketched by Lange, is hardly to be ranked with either. Having formally acknowledged God as the great first cause, he immediately dropped the idea, applied the known laws of mechanics to the atoms, and deduced from them all vital phenomena. He defended Epicurus, and dwelt upon his purity, both of doctrine and of life. True he was a heathen, but so was Aristotle. Epicurus assailed superstition and religion, and rightly, because he did not know the true religion. He thought that the gods neither rewarded nor punished, and he adored them purely in consequence of their completeness: here we see, says Gassendi, the reverence of the child, instead of the fear of the slave. The errors of Epicurus shall be corrected, and the body of his truth retained. Gassendi then proceeds, as any heathen might have done, to build up the world, and all that therein is, of atoms and molecules. God, who created earth and water, plants and animals, produced in the first place a definite number of atoms, which constituted the seed of all things. Then began that series of combinations and decompositions which now goes on, and which will continue in future. The principle of every change resides in matter. In artificial productions the moving principle is different from the material worked upon; but in nature the agent works within, being the most active and mobile part of the material itself. Thus this bold ecclesiastic, without incurring the censure of the church or the world, contrives to outstrip Mr. Darwin. The same cast of mind which caused him to detach the Creator from his universe, led him also to detach the soul from the body, though to the body he ascribes an influence so large as to render the soul almost unnecessary. The aberrations of reason were, in his view, an affair of the material brain. Mental disease is brain-disease; but then the immortal reason sits apart, and cannot be touched by the disease. The errors of madness are those of the instrument, not of the performer.

It may be more than a mere result of education, connecting itself, probably, with the deeper mental structure of the two men, that the idea of Gassendi, above enunciated, is substantially the same as that expressed by Professor Clerk Maxwell, at the close of the very able lecture delivered by him at Bradford in 1873. According to both philosophers, the atoms, if I understand aright, are *prepared materials*, which, formed once for all by the Eternal, produce by their subsequent interaction all the phenomena of the material world. There seems to be this difference, however, between Gassendi and Maxwell. The one *postulates*, the other *infers* his first cause. In his 'manufactured articles,' as he calls the atoms, Professor Maxwell finds the basis of an induction, which enables him to scale philosophic heights considered inaccessible by Kant, and to take the logical step from the atoms to their Maker

Accepting here the leadership of Kant, I doubt the legitimacy of Maxwell's logic; but it is impossible not to feel the ethic glow with which his lecture concludes. There is, moreover, a very noble strain of eloquence in his description of the steadfastness of the atoms: 'Natural causes, as we know, are at work, which tend to modify, if they do not at length destroy, all the arrangements and dimensions of the earth and the whole solar system. But though in the course of ages catastrophes have occurred and may yet occur in the heavens, though ancient systems may be dissolved and new systems evolved out of their ruins, the molecules out of which these systems are built—the foundation stones of the material universe—remain unbroken and unworn.'

The atomic doctrine, in whole or in part, was entertained by Bacon, Descartes, Hobbes, Locke, Newton, Boyle, and their successors, until the chemical law of multiple proportions enabled Dalton to confer upon it an entirely new significance. In our day there are secessions from the theory, but it still stands firm. Loschmidt, Stoney, and Sir William Thomson have sought to determine the sizes of the atoms, or rather to fix the limits between which their sizes lie; while the discourses of Williamson and Maxwell delivered in Bradford in 1873 illustrate the present hold of the doctrine upon the foremost scientific minds. In fact, it may be doubted whether, wanting this fundamental conception, a theory of the material universe is capable of scientific statement.

§ 5.

Ninety years subsequent to Gassendi the doctrine of bodily instruments, as it may be called, assumed immense importance in the hands of Bishop Butler, who, in his famous 'Analogy of Religion,' developed, from his own point of view, and with consummate sagacity, a similar idea. The Bishop still influences many superior minds; and it will repay us to dwell for a moment on his views. He draws the sharpest distinction between our real selves and our bodily instruments. He does not, as far as I remember, use the word soul, possibly because the term was so hackneyed in his day, as it had been for many generations previously. But he speaks of 'living powers,' 'perceiving or percipient powers,' 'moving agents,' 'ourselves,' in the same sense as we should employ the term soul. He dwells upon the fact that limbs may be removed, and mortal diseases assail the body, the mind, almost up to the moment of death, remaining clear. He refers to sleep and to swoon, where the 'living powers' are suspended but not destroyed. He considers it quite as easy to conceive of existence out of our bodies as in them; that we may animate a succession of bodies, the dissolution of all of them having no more tendency to dissolve our real selves, or 'deprive us of living faculties—the faculties of perception and action—than the dissolution of any foreign matter which we are capable of receiving impressions from, or making use of for the common occasions of life.' This is the key of the Bishop's position: 'our organised bodies are no more a part of ourselves than any other matter around us.' In proof of this he calls attention to the use of glasses, which 'prepare objects' for the 'percipient power' exactly as the eye does. The eye itself is no more percipient than the glass; is quite as much the instrument of the true self, and also as foreign to the true self, as the glass is. 'And if we see with our eyes only in the same manner as we do with glasses, the like may justly be concluded from analogy of all our senses.'

Lucretius, as you are aware, reached a precisely opposite conclusion: and it certainly would be interesting, if not profitable, to us all, to hear what he would or could urge in opposition to the reasoning of the Bishop. As a brief discussion of the point will enable us to see the bearings of an important question, I will here permit a disciple of Lucretius to try the strength of the Bishop's position, and then allow the Bishop to retaliate, with the view of rolling back, if he can, the difficulty upon Lucretius.

The argument might proceed in this fashion:—

'Subjected to the test of mental presentation (*Vorstellung*), your views, most honoured prelate, would offer to many minds a great, if not an insuperable, difficulty. You speak of "living powers," "percipient or perceiving powers," and "ourselves;" but can you form a mental picture of any of these, apart from the organism through which it is supposed to act? Test yourself honestly, and see whether you possess any faculty that would enable you to form such a conception. The true self has a local habitation in each of us; thus localised, must it not possess a form? If so, what form? Have you ever for a moment realised it? When a leg is amputated the body is divided into two parts; is the true self in both of them or in one? Thomas Aquinas might say in both; but not you, for you appeal to the consciousness associated with one of the two parts, to prove that the other is foreign matter. Is consciousness, then, a necessary element of the true self? If so, what do you say to the case of the whole body being deprived of consciousness? If not, then on what grounds do you deny any portion of the true self to the severed limb? It seems very singular that, from the beginning to the end of your admirable book (and no one admires its sober strength more than I do), you never once mention the brain or nervous system. You begin at one end of the body, and show that its parts may be removed without prejudice to the perceiving power. What if you begin at the other end, and remove, instead of the leg, the brain? The body, as before, is divided into two parts; but both are now in the same predicament, and neither can be appealed to to prove that the other is foreign matter. Or, instead of going so far as to remove the brain itself, let a certain portion of its bony covering be removed, and let a rhythmic series of pressures and relaxations of pressure be applied to the soft substance. At every pressure "the faculties of perception and of action" vanish; at every relaxation of pressure they are restored. Where, during the intervals of pressure, is the perceiving power? I once had the discharge of a large Leyden battery passed unexpectedly through me: I felt nothing, but was simply blotted out of conscious existence for a sensible interval. Where was my true self during that interval? Men who have recovered from lightning-stroke have been much longer in the same state; and indeed in cases of ordinary concussion of the brain, days may elapse during which no experience is registered in consciousness. Where is the man himself during the period of insensibility? You may say that I beg the question when I assume the man to have been unconscious, that he was really conscious all the time, and has simply forgotten what had occurred to him. In reply to this, I can only say that no one need shrink from the worst tortures that superstition ever invented, if only so felt and so remembered. I do not think your theory of instruments goes at all to the bottom of the matter. A telegraph-operator has his instruments, by means of which he converses with the world; our bodies possess a nervous system, which plays a similar part between the perceiving power and external things. Cut the wires of the operator, break his battery, demagnetise his needle; by this means you certainly sever his connection with the world; but, inasmuch as these are real instruments, their destruction does not touch the man who uses them. The operator survives, *and he knows that he survives.* What is there, I would ask, in the human system that answers to this conscious survival of the operator when the battery of the brain is so disturbed as to produce insensibility, or when it is destroyed altogether?

'Another consideration, which you may regard as slight, presses upon me with some force. The brain may change from health to disease, and through such a change the most exemplary man may be converted into a debauchee or a murderer. My very noble and approved good master had, as you know, threatenings of lewdness introduced into his brain by his jealous wife's philter; and sooner than permit himself to run even the risk of yielding to these base promptings he slew himself. How could the hand of Lucretius have been thus turned against himself if the real Lucretius remained as before? Can the brain or can it not act in this distempered way without the intervention of the immortal reason? If it can, then it is a prime mover which requires only healthy regulation to render it reasonably self-acting, and there is no apparent need of your immortal reason at all. If it cannot, then the immortal reason, by its mischievous activity in operating upon a broken instrument, must have the credit of committing every imaginable extravagance and crime. I think, if you will allow me to say so, that the gravest consequences are likely to flow from your estimate of the body. To regard the brain as you would a staff or an eyeglass—to shut your eyes to all its mystery, to the perfect correlation of its condition and our consciousness, to the fact that a slight excess or defect of blood in it produces the very swoon to which you refer, and that in relation to it our meat, and drink, and air, and exercise, have a perfectly transcendental value and significance—to forget all this does, I think, open a way to innumerable errors in our habits of life, and may possibly, in some cases, initiate and foster that very disease, and consequent mental ruin, which a wiser appreciation of this mysterious organ would have avoided.'

I can imagine the Bishop thoughtful after hearing this argument. He was not the man to allow anger to mingle with the consideration of a point of this kind. After due reflection, and having strengthened himself by that honest contemplation of the facts which was habitual with him, and which includes the desire to give even adverse reasonings their due weight, I can suppose the Bishop to proceed thus: 'You will remember that in the "Analogy of Religion," of which you have so kindly spoken, I did not profess to prove anything absolutely, and that I over and over again acknowledged and insisted on the smallness of our knowledge, or rather the depth of our ignorance, as regards the whole system of the universe. My object was to show my deistical friends, who set forth so eloquently the beauty and beneficence of Nature and the Ruler thereof, while they had nothing but scorn for the so-called absurdities of the Christian scheme, that they were in no better condition than we were, and that, for every difficulty found upon our side, quite as great a difficulty was to be found upon theirs. I will now, with your permission, adopt a similar line of argument. You are a Lucretian, and from the combination and separation of insensate atoms deduce all terrestrial things, including organic forms and their phenomena. Let me tell you in the first instance how far I am prepared to go with you. I admit that you can build crystalline forms out of this play of molecular force; that the diamond, amethyst, and snow-star are truly wonderful structures which are thus produced. I will go farther and acknowledge that even a tree or flower might in this way be organised. Nay, if you can show me an animal without sensation, I will concede to you that it also might be put together by the suitable play of molecular force.

'Thus far our way is clear, but now comes my difficulty. Your atoms are individually without sensation, much more are they without intelligence. May I ask you, then, to try your hand upon this problem. Take your dead hydrogen atoms, your dead oxygen atoms, your dead carbon atoms, your dead nitrogen atoms, your dead phosphorus atoms, and all the other atoms, dead as grains of shot, of which the brain is formed. Imagine them separate and sensationless; observe them running together and forming all imaginable combinations. This, as a purely mechanical process, is *seeable* by the mind. But can you see, or dream, or in any way imagine, how out of that mechanical act, and from these individually dead atoms, sensation, thought, and emotion are to rise? Are you likely to extract Homer out of the rattling of dice, or the Differential Calculus out of the clash of billiard-balls? I am not all bereft of this *Vorstellungs-Kraft* of which you speak, nor am I, like so many of my brethren, a mere vacuum as regards scientific knowledge. I can follow a particle of musk until it reaches the olfactory nerve; I can follow the waves of sound until their tremors reach the water of the labyrinth, and set the otoliths and Corti's fibres in motion; I can also visualise the waves of ether as they cross the eye and hit the retina. Nay more, I am able to pursue to the central organ the motion thus imparted at the periphery, and to see in idea the very molecules of the brain thrown into tremors. My insight is not baffled by these physical processes. What baffles and bewilders me is the notion that from those physical tremors things so utterly incongruous with them as sensation, thought, and emotion can be derived. You may say, or think, that this issue of consciousness from the clash of atoms is not more incongruous than the flash of light from the union of oxygen and hydrogen. But I beg to say that it is. For such incongruity as the flash possesses is that which I now force upon your attention. The 'flash' is an affair of consciousness, the objective counterpart of which is a vibration. It is a flash only by your interpretation. *You* are the cause of the apparent incongruity; and *you* are the thing that puzzles me. I need not remind you that the great Leibnitz felt the difficulty which I feel; and that to get rid of this monstrous deduction of life from death he displaced your atoms by his monads, which were more or less perfect mirrors of the universe, and out of the summation and integration of which he supposed all the phenomena of life—sentient, intellectual, and emotional—to arise.

'Your difficulty, then, as I see you are ready to admit, is quite as great as mine. You cannot satisfy the human understanding in its demand for logical continuity between molecular processes and the phenomena of consciousness. This is a rock on which Materialism must inevitably split whenever it pretends to be a complete philosophy of life. What is the moral, my Lucretian? You and I are not likely to indulge in ill-temper in the discussion of these great topics, where we see so much room for honest differences of opinion. But there are people of less wit or more bigotry (I say it with humility), on both sides, who are ever ready to mingle anger and vituperation with such discussions. There are, for example, writers of note and influence at the present day, who are not ashamed publicly to assume the "deep personal sin" of a great logician to be the cause of his unbelief in a theologic dogma.[1] And there are others who hold that we, who cherish our noble Bible, wrought as it has been into the constitution of our forefathers, and by inheritance into us, must necessarily be hypocritical and insincere. Let us disavow and discountenance such people, cherishing the unswerving faith that what is good and true in both our arguments will be preserved for the benefit of humanity, while all that is bad or false will disappear.'

I hold the Bishop's reasoning to be unanswerable, and his liberality to be worthy of imitation

It is worth remarking that in one respect the Bishop was a product of his age. Long previous to his day the nature of the soul had been so favourite and general a topic of discussion, that, when the students of the Italian Universities wished to know the leanings of a new Professor, they at once requested him to lecture upon the soul. About the time of Bishop Butler the question was not only agitated but extended. It was seen by the clear-witted men who entered this arena, that many of their best arguments applied equally to brutes and men. The Bishop's arguments were of this character. He saw it, admitted it, took the consequence, and boldly embraced the whole animal world in his scheme of immortality.

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[1] This is the aspect under which the late Editor of the 'Dublin Review' presented to his readers the memory of John Stuart Mill. I can only say, that I would as soon take my chance in the other world, in the company of the 'unbeliever,' as in that of his Jesuit detractor. In Dr. Ward we have an example of a wholesome and vigorous nature, soured and perverted by a poisonous creed.

§ 6.

Bishop Butler accepted with unwavering trust the chronology of the Old Testament, describing it as 'confirmed by the natural and civil history of the world, collected from common historians, from the state of the earth, and from the late inventions of arts and sciences.' These words mark progress; and they must seem somewhat hoary to the Bishop's successors of to-day. It is hardly necessary to inform you that since his time the domain of the naturalist has been immensely extended—the whole science of geology, with its astounding revelations regarding the life of the ancient earth, having been created. The rigidity of old conceptions has been relaxed, the public mind being rendered gradually tolerant of the idea that not for six thousand, nor for sixty thousand, nor for six thousand thousand, but for æons embracing untold millions of years, this earth has been the theatre of life and death. The riddle of the rocks has been read by the geologist and palæontologist, from sub-cambrian depths to the deposits thickening over the sea-bottoms of to-day. And upon the leaves of that stone book are, as you know, stamped the characters, plainer and surer than those formed by the ink of history, which carry the mind back into abysses of past time, compared with which the periods which satisfied Bishop Butler cease to have a visual angle.

The lode of discovery once struck, those petrified forms in which life was at one time active, increased to multitudes and demanded classification. They were grouped in genera, species, and varieties, according to the degree of similarity subsisting between them. Thus confusion was avoided, each object being found in the pigeon-hole appropriated to it and to its fellows of similar morphological or physiological character. The general fact soon became evident that none but the simplest forms of life lie lowest down; that, as we climb higher among the superimposed strata, more perfect forms appear. The change, however, from form to form was not continuous, but by steps—some small, some great. 'A section,' says Mr. Huxley, 'a hundred feet thick will exhibit at different heights a dozen species of Ammonite, none of which passes beyond the particular zone of limestone, or clay, into the zone below it, or into that above it.' In the presence of such facts it was not possible to avoid the question: Have these forms, showing, though in broken stages, and with many irregularities, this unmistakable general advance, being subjected to no continuous law of growth or variation? Had our education been purely scientific, or had it been sufficiently detached from influences which, however ennobling in another domain, have always proved hindrances and delusions when introduced as factors into the domain of physics, the scientific mind never could have swerved from the search for a law of growth, or allowed itself to accept the anthropomorphism which regarded each successive stratum as a kind of mechanic's bench for the manufacture of new species out of all relation to the old.

Biassed, however, by their previous education, the great majority of naturalists invoked a special creative act to account for the appearance of each new group of organisms. Doubtless numbers of them were clear-headed enough to see that this was no explanation at all—that, in point of fact, it was an attempt, by the introduction of a greater difficulty, to account for a less. But, having nothing to offer in the way of explanation, they for the most part held their peace. Still the thoughts of reflecting men naturally and necessarily simmered round the question. De Maillet, a contemporary of Newton, has been brought into notice by Professor Huxley as one who 'had a notion of the modifiability of living forms.' The late Sir Benjamin Brodie, a man of highly philosophic mind, often drew my attention to the fact that, as early as 1794, Charles Darwin's grandfather was the pioneer of Charles Darwin.[1] In 1801, and in subsequent years, the celebrated Lamarck, who, through the vigorous exposition of his views by the author of the 'Vestiges of Creation,' rendered the public mind perfectly familiar with the idea of evolution, endeavoured to show the development of species out of changes of habit and external condition. In 1813 Dr. Wells, the founder of our present theory of Dew, read before the Royal Society a paper in which, to use the words of Mr. Darwin, 'he distinctly recognises the principle of natural selection; and this is the first recognition that has been indicated.' The thoroughness and skill with which Wells pursued his work, and the obvious independence of his character, rendered him long ago a favourite with me; and it gave me the liveliest pleasure to alight upon this additional testimony to his penetration. Professor Grant, Mr. Patrick Matthew, Von Buch, the author of the 'Vestiges,' D'Halloy, and others, by the enunciation of opinions more or less clear and correct, showed that the question had been fermenting long prior to the year 1858, when Mr. Darwin and Mr. Wallace simultaneously, but independently, placed their closely concurrent views before the Linnean Society.[2]

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[1] 'Zoonomia,' vol. i. pp. 500–510.

[2] In 1855 Mr. Herbert Spencer ('Principles of Psychology,' 2nd edit. vol. i. p. 465) expressed 'the belief that life under all its forms has arisen by an unbroken evolution, and through the instrumentality of what are called natural causes.' This was my belief also at that time.

These papers were followed in 1859 by the publication of the first edition of the 'Origin of Species.' All great things come slowly to the birth. Copernicus, as I informed you, pondered his great work for thirty-three years. Newton for nearly twenty years kept the idea of Gravitation before his mind; for twenty years also he dwelt upon his discovery of Fluxions, and doubtless would have continued to make it the object of his private thought, had he not found Leibnitz upon his track. Darwin for two-and-twenty years pondered the problem of the origin of species, and doubtless he would have continued to do so had he not found Wallace upon his track.[1] A concentrated, but full and powerful, epitome of his labours was the consequence. The book was by no means an easy one; and probably not one in every score of those who then attacked it, had read its pages through, or were competent to grasp their significance if they had. I do not say this merely to discredit them: for there were in those days some really eminent scientific men, entirely raised above the heat of popular prejudice, and willing to accept any conclusion that science had to offer, provided it was duly backed by fact and argument, who entirely mistook Mr. Darwin's views. In fact, the work needed an expounder, and it found one in Mr. Huxley. I know nothing more admirable in the way of scientific exposition than those early articles of his on the origin of species. He swept the curve of discussion through the really significant points of the subject, enriched his exposition with profound original remarks and reflections, often summing up in a single pithy sentence an argument which a less compact mind would have spread over pages. But there is one impression made by the book itself which no exposition of it, however luminous, can convey; and that is the impression of the vast amount of labour, both of observation and of thought, implied in its production. Let us glance at its principles.

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[1] The behaviour of Mr. Wallace in relation to this subject has been dignified in the highest degree.

It is conceded on all hands that what are called 'varieties' are continually produced. The rule is probably without exception. No chick, or child, is in all respects and particulars the counterpart of its brother and sister; and in such differences we have 'variety' incipient. No naturalist could tell how far this variation could be carried; but the great mass of them held that never, by any amount of internal or external change, nor by the mixture of both, could the offspring of the same progenitor so far deviate from each other as to constitute different species. The function of the experimental philosopher is to combine the conditions of Nature and to produce her results; and this was the method of Darwin.[1] He made himself acquainted with what could, without any manner of doubt, be done in the way of producing variation. He associated himself with pigeon-fanciers—bought, begged, kept, and observed every breed that he could obtain. Though derived from a common stock, the diversities of these pigeons were such that 'a score of them might be chosen which, if shown to an ornithologist, and he were told that they were wild birds, would certainly be ranked by him as well-defined species.' The simple principle which guides the pigeon-fancier, as it does the cattle-breeder, is the selection of some variety that strikes his fancy, and the propagation of this variety by inheritance With his eye still directed to the particular appearance which he wishes to exaggerate, he selects it as it reappears in successive broods, and thus adds increment to increment until an astonishing amount of divergence from the parent type is effected. The breeder in this case does not produce the *elements* of the variation. He simply observes them, and by selection adds them together until the required result has been obtained. 'No man,' says Mr. Darwin, 'would ever try to make a fantail till he saw a pigeon with a tail developed in some slight degree in an unusual manner, or a pouter until he saw a pigeon with a crop of unusual size.' Thus nature gives the hint, man acts upon it, and by the law of inheritance exaggerates the deviation.

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[1] The first step only towards experimental demonstration has been taken. Experiments now begun might, a couple of centuries hence, furnish data of incalculable value, which ought to be supplied to the science of the future.

Having thus satisfied himself by indubitable facts that the organisation of an animal or of a plant (for precisely the same treatment applies to plants) is to some extent plastic, he passes from variation under domestication to variation under nature. Hitherto we have dealt with the adding together of small changes by the conscious selection of man. Can Nature thus select? Mr. Darwin's answer is, 'Assuredly she can.' The number of living things produced is far in excess of the number that can be supported; hence at some period or other of their lives there must be a struggle for existence. And what is the infallible result? If one organism were a perfect copy of the other in regard to strength, skill, and agility, external conditions would decide. But this is not the case. Here we have the fact of variety offering itself to nature, as in the former instance it offered itself to man; and those varieties which are least competent to cope with surrounding conditions will infallibly give way to those that are most competent. To use a familar proverb, the weak-est goes to the wall. But the triumphant fraction again breeds to over-production, transmitting the qualities which secured its maintenance, but transmitting them in different degrees. The struggle for food again supervenes, and those to whom the favourable quality has been transmitted in excess, will triumph as before.

It is easy to see that we have here the addition of increments favourable to the individual, still more rigorously carried out than in the case of domestication; for not only are unfavourable specimens not selected by nature, but they are destroyed. This is what Mr. Darwin calls 'Natural Selection,' which acts by the preservation and accumulation of small inherited modifications, each profitable to the preserved being. With this idea he interpenetrates and leavens the vast store of facts that he and others have collected. We cannot, without shutting our eyes through fear or prejudice, fail to see that Darwin is here dealing, not with imaginary, but with true causes; nor can we fail to discern what vast modifications may be produced by natural selection in periods sufficiently long. Each individual increment may resemble what mathematicians call a 'differential' (a quantity indefinitely small); but definite and great changes may obviously be produced by the integration of these infinitesimal quantities, through practically infinite time.

If Darwin, like Bruno, rejects the notion of creative power, acting after human fashion, it certainly is not because he is unacquainted with the numberless exquisite adaptations, on which this notion of a supernatural Artificer has been founded. His book is a repository of the most startling facts of this description. Take the marvellous observation which he cites from Dr. Krüger, where a bucket, with an aperture serving as a spout, is formed in an orchid. Bees visit the flower: in eager search of material for their combs, they push each other into the bucket, the drenched ones escaping from their involuntary bath by the spout. Here they rub their backs against the viscid stigma of the flower and obtain glue; then against the pollen-masses, which are thus stuck to the back of the bee and carried away. 'When the bee, so provided, flies to another flower, or to the same flower a second time, and is pushed by its comrades into the bucket, and then crawls out by the passage, the pollen-mass upon its back necessarily comes first into contact with the viscid stigma,' which takes up the pollen; and this is how that orchid is fertilised. Or take this other case of the *Catasetum*. 'Bees visit these flowers in order to gnaw the labellum; in doing this they inevitably touch a long, tapering, sensitive projection. This, when touched, transmits a sensation or vibration to a certain membrane, which is instantly ruptured, setting free a spring, by which the pollen-mass is shot forth like an arrow in the right direction, and adheres by its viscid extremity to the back of the bee.' In this way the fertilising pollen is spread abroad.

It is the mind thus stored with the choicest materials of the teleologist that rejects teleology, seeking to refer these wonders to natural causes. They illustrate, according to him, the method of nature, not the 'technic' of a manlike Artificer. The beauty of flowers is due to natural selection. Those that distinguish themselves by vividly contrasting colours from the surrounding green leaves are most readily seen, most frequently visited by insects, most often fertilised, and hence most favoured by natural selection. Coloured berries also readily attract the attention of birds and beasts, which feed upon them, spread their manured seeds abroad, thus giving trees and shrubs possessing such berries a greater chance in the struggle for existence.

With profound analytic and synthetic skill, Mr. Darwin investigates the cell-making instinct of the hive-bee. His method of dealing with it is representative. He falls back from the more perfectly to the less perfectly developed instinct—from the hive-bee to the humble bee, which uses its own cocoon as a comb, and to classes of bees of intermediate skill, endeavouring to show how the passage might be gradually made from the lowest to the highest. The saving of wax is the most important point in the economy of bees. Twelve to fifteen pounds of dry sugar are said to be needed for the secretion of a single pound of wax. The quantities of nectar necessary for the wax must therefore be vast; and every improvement of constructive instinct which results in the saving of wax is a direct profit to the insect's life. The time that would otherwise be devoted to the making of wax, is devoted to the gathering and storing of honey for winter food. Mr. Darwin passes from the humble bee with its rude cells, through the Melipona with its more artistic cells, to the hive-bee with its astonishing architecture. The bees place themselves at equal distances apart upon the wax, sweep and excavate equal spheres round the selected points. The spheres intersect, and the planes of intersection are built up with thin laminæ. Hexagonal cells are thus formed. This mode of treating such questions is, as I have said, representative. The expositor habitually retires from the more perfect and complex, to the less perfect and simple, and carries you with him through stages of *perfecting*—adds increment to increment of infinitesimal change, and in this way gradually breaks down your reluctance to admit that the exquisite climax of the whole could be a result of natural selection.

Mr. Darwin shirks no difficulty; and, saturated as the subject was with his own thought, he must have known, better than his critics, the weakness as well as the strength of his theory. This of course would be of little avail were his object a temporary dialectic victory, instead of the establishment of a truth which he means to be everlasting. But he takes no pains to disguise the weakness he has discerned; nay, he takes every pains to bring it into the strongest light. His vast resources enable him to cope with objections started by himself and others, so as to leave the final impression upon the reader's mind that, if they be not completely answered, they certainly are not fatal. Their negative force being thus destroyed, you are free to be influenced by the vast positive mass of evidence he is able to bring before you. This largeness of knowledge, and readiness of resource, render Mr. Darwin the most terrible of antagonists. Accomplished naturalists have levelled heavy and sustained criticisms against him—not always with the view of fairly weighing his theory, but with the express intention of exposing its weak points only This does not irritate him. He treats every objection with a soberness and thoroughness which even Bishop Butler might be proud to imitate, surrounding each fact with its appropriate detail, placing it in its proper relations, and usually giving it a significance which, as long as it was kept isolated, failed to appear. This is done without a trace of ill-temper. He moves over the subject with the passionless strength of a glacier; and the grinding of the rocks is not always without a counterpart in the logical pulverisation of the objector. But though in handling this mighty theme all passion has been stilled, there is an emotion of the intellect, incident to the discernment of new truth, which often colours and warms the pages of Mr. Darwin.

His success has been great; and this implies not only the solidity of his work, but the preparedness of the public mind for such a revelation. On this head, a remark of Agassiz impressed me more than anything else. Sprung from a race of theologians, this celebrated man combated to the last the theory of natural selection. One of the many times I had the pleasure of meeting him in the United States was at Mr. Winthrop's beautiful residence at Brookline, near Boston. Rising from luncheon, we all halted as if by common consent, in front of a window, and continued there a discussion which had been started at table. The maple was in its autumn glory, and the exquisite beauty of the scene outside seemed, in my case, to interpenetrate without disturbance the intellectual action. Earnestly, almost sadly, Agassiz turned, and said to the gentlemen standing round, 'I confess that I was not prepared to see this theory received as it has been by the best intellects of our time. Its success is greater than I could have thought possible.'

§ 7.

In our day grand generalisations have been reached. The theory of the origin of species is but one of them. Another, of still wider grasp and more radical significance, is the doctrine of the Conservation of Energy, the ultimate philosophical issues of which are as yet but dimly seen—that doctrine which 'binds nature fast in fate,' to an extent not hitherto recognised, exacting from every antecedent its equivalent consequent, from every consequent its equivalent antecedent, and bringing vital as well as physical phenomena under the dominion of that law of causal connection which, so far as the human understanding has yet pierced, asserts itself everywhere in nature. Long in advance of all definite experiment upon the subject, the constancy and indestructibility of matter had been affirmed; and all subsequent experience justified the affirmation. Mayer extended the attribute of indestructibility to energy, applying it in the first instance to inorganic,[1] and afterwards with profound insight to organic nature. The vegetable world, though drawing all its nutriment from invisible sources, was proved incompetent to generate anew either matter or force. Its matter is for the most part transmuted gas; its force transformed solar force. The animal world was proved to be equally uncreative, all its motive energies being referred to the combustion of its food. The activity of each animal, as a whole, was proved to be the transferred activity of its molecules. The muscles were shown to be stores of mechanical energy, potential until unlocked by the nerves, and then resulting in muscular contractions. The speed at which messages fly to and fro along the nerves was determined by Helmholtz, and found to be, not, as had been previously supposed, equal to that of light or electricity, but less than the speed of sound—less even than that of an eagle.

This was the work of the physicist: then came the conquests of the comparative anatomist and physiologist, revealing the structure of every animal, and the function of every organ in the whole biological series, from the lowest zoophyte up to man. The nervous system had been made the object of profound and continued study, the wonderful and, at bottom, entirely mysterious controlling power which it exercises over the whole organism, physical and mental, being recognised more and more. Thought could not be kept back from a subject so profoundly suggestive. Besides the physical life dealt with by Mr. Darwin, there is a psychical life presenting similar gradations, and asking equally for a solution. How are the different grades and orders of Mind to be accounted for? What is the principle of growth of that mysterious power which on our planet culminates in Reason? These are questions which, though not thrusting themselves so forcibly upon the attention of the general public, had not only occupied many reflecting minds, but had been formally broached by one of them before the 'Origin of Species' appeared.

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[1] Dr. Berthold has shown that Leibnitz had sound views regarding the conservation of energy in inorganic nature.

With the mass of materials furnished by the physicist and physiologist in his hands, Mr. Herbert Spencer, twenty years ago, sought to graft upon this basis a system of psychology; and two years ago a second and greatly amplified edition of his work appeared. Those who have occupied themselves with the beautiful experiments of Plateau will remember that when two spherules of olive-oil suspended in a mixture of alcohol and water of the same density as the oil, are brought together, they do not immediately unite. Something like a pellicle appears to be formed around the drops, the rupture of which is immediately followed by the coalescence of the globules into one. There are organisms whose vital actions are almost as purely physical as the coalescence of such drops of oil. They come into contact and fuse themselves thus together. From such organisms to others a shade higher, from these to others a shade higher still, and on through an ever-ascending series, Mr. Spencer conducts his argument. There are two obvious factors to be here taken into account—the creature and the medium in which it lives, or, as it is often expressed, the organism and its environment. Mr. Spencer's fundamental principle is, that between these two factors there is incessant interaction. The organism is played upon by the environment, and is modified to meet the requirements of the environment. Life he defines to be 'a continuous adjustment of internal relations to external relations.'

In the lowest organisms we have a kind of tactual sense diffused over the entire body; then, through impressions from without and their corresponding adjustments, special portions of the surface become more responsive to stimuli than others. The senses are nascent, the basis of all of them being that simple tactual sense which the sage Democritus recognised 2,300 years ago as their common progenitor. The action of light, in the first instance, appears to be a mere disturbance of the chemical processes in the animal organism, similar to that which occurs in the leaves of plants. By degrees the action becomes localised in a few pigment-cells, more sensitive to light than the surrounding tissue. The eye is incipient. At first it is merely capable of revealing differences of light and shade produced by bodies close at hand. Followed, as the interception of the light commonly is, by the contact of the closely adjacent opaque body, sight in this condition becomes a kind of 'anticipatory touch.' The adjustment continues; a slight bulging out of the epidermis over the pigment-granules supervenes. A lens is incipient, and, through the operation of infinite adjustments, at length reaches the perfection that it displays in the hawk and eagle. So of the other senses; they are special differentiations of a tissue which was originally vaguely sensitive all over.

With the development of the senses, the adjustments between the organism and its environment gradually extend in *space*, a multiplication of experiences and a corresponding modification of conduct being the result.

The adjustments also extend in *time*, covering continually greater intervals. Along with this extension in space and time the adjustments also increase in speciality and complexity, passing through the various grades of brute life, and prolonging themselves into the domain of reason. Very striking are Mr. Spencer's remarks regarding the influence of the sense of touch upon the development of intelligence. This is, so to say, the mother-tongue of all the senses, into which they must be translated to be of service to the organism. Hence its importance. The parrot is the most intelligent of birds, and its tactual power is also greatest. From this sense it gets knowledge, unattainable by birds which cannot employ their feet as hands. The elephant is the most sagacious of quadrupeds – its tactual range and skill, and the consequent multiplication of experiences, which it owes to its wonderfully adaptable trunk, being the basis of its sagacity. Feline animals, for a similar cause, are more sagacious than hoofed animals,—atonement being to some extent made in the case of the horse, by the possession of sensitive prehensile lips. In the *Primates* the evolution of intellect and the evolution of tactual appendages go hand in hand. In the most intelligent anthropoid apes we find the tactual range and delicacy greatly augmented, new avenues of knowledge being thus opened to the animal. Man crowns the edifice here, not only in virtue of his own manipulatory power, but through the enormous extension of his range of experience, by the invention of instruments of precision, which serve as supplemental senses and supplemental limbs. The reciprocal action of these is finely described and illustrated That chastened intellectual emotion to which I have referred in connection with Mr. Darwin, is not absent in Mr. Spencer. His illustrations possess at times exceeding vividness and force; and from his style on such occasions it is to be inferred, that the ganglia of this Apostle of the Understanding are sometimes the seat of a nascent poetic thrill.

It is a fact of supreme importance that actions, the performance of which at first requires even painful effort and deliberation, may, by habit, be rendered automatic. Witness the slow learning of its letters by a child, and the subsequent facility of reading in a man, when each group of letters which forms a word is instantly, and without effort, fused to a single perception. Instance the billiard-player, whose muscles of hand and eye, when he reaches the perfection of his art, are unconsciously co-ordinated. Instance the musician, who, by practice, is enabled to fuse a multitude of arrangements, auditory, tactual, and muscular, into a process of automatic manipulation. Combining such facts with the doctrine of hereditary transmission, we reach a theory of Instinct. A chick, after coming out of the egg, balances itself correctly, runs about, picks up food, thus showing that it possesses a power of directing its movements to definite ends. How did the chick learn this very complex co-ordination of eyes, muscles, and beak? It has not been individually taught; its personal experience is *nil*; but it has the benefit of ancestral experience. In its inherited organisation are registered the powers which it displays at birth. So also as regards the instinct of the hive-bee, already referred to. The distance at which the insects stand apart when they sweep their hemispheres and build their cells is 'organically remembered.' Man also carries with him the physical texture of his ancestry, as well as the inherited intellect bound up with it. The defects of intelligence during infancy and youth are probably less due to a lack of individual experience, than to the fact that in early life the cerebral organisation is still incomplete. The period necessary for completion varies with the race, and with the individual. As a round shot outstrips the rifled bolt on quitting the muzzle of the gun, so the lower race, in childhood, may outstrip the higher. But the higher eventually overtakes the lower, and surpasses it in range. As regards individuals, we do not always find the precocity of youth prolonged to mental power in maturity; while the dulness of boyhood is sometimes strikingly contrasted with the intellectual energy of after years. Newton, when a boy, was weakly, and he showed no particular aptitude at school; but in his eighteenth year he went to Cambridge, and soon afterwards astonished his teachers by his power of dealing with geometrical problems. During his quiet youth his brain was slowly preparing itself to be the organ of those energies which he subsequently displayed.

By myriad blows (to use a Lucretian phrase) the image and superscription of the external world are stamped as states of consciousness upon the organism, the depth of the impression depending on the number of the blows. When two or more phenomena occur in the environment invariably together, they are stamped to the same depth or to the same relief, and indissolubly connected. And here we come to the threshold of a great question. Seeing that he could in no way rid himself of the consciousness of Space and Time, Kant assumed them to be necessary 'forms of intuition,' the moulds and shapes into which our intuitions are thrown, belonging to ourselves, and without objective existence. With unexpected power and success, Mr. Spencer brings the hereditary experience theory, as he holds it, to bear upon this question. 'If there exist certain external relations which are experienced by all organisms at all instants of their waking lives—relations which are absolutely constant and universal—there will be established answering internal relations, that are absolutely constant and universal. Such relations we have in those of Space and Time. As the substratum of all other relations of the Non-Ego, they must be responded to by conceptions that are the substrata of all other relations in the Ego. Being the constant and infinitely repeated elements of thought, they must become the automatic elements of thought—the elements of thought which it is impossible to get rid of—the "forms of intuition."'

Throughout this application and extension of Hartley's and Mill's 'Law of Inseparable Association,' Mr. Spencer stands upon his own ground, invoking, instead of the experiences of the individual, the registered experiences of the race. His overthrow of the restriction of experience to the individual is, I think, complete. That restriction ignores the power of organising experience, furnished at the outset to each individual; it ignores the different degrees of this power possessed by different races, and by different individuals of the same race. Were there not in the human brain a potency antecedent to all experience, a dog or a cat ought to be as capable of education as a man. These predetermined internal relations are independent of the experiences of the individual. The human brain is the 'organised register of infinitely numerous experiences received during the evolution of life, or rather during the evolution of that series of organisms through which the human organism has been reached. The effects of the most uniform and frequent of these experiences have been successively bequeathed, principal and interest, and have slowly mounted to that high intelligence which lies latent in the brain of the infant. Thus it happens that the European inherits from twenty to thirty cubic inches more of brain than the Papuan. Thus it happens that faculties, as of music, which scarcely exist in some inferior races, become congenital in superior ones. Thus it happens that out of savages unable to count up to the number of their fingers, and speaking a language containing only nouns and verbs, arise at length our Newtons and Shakspeares.'

§ 8.

At the outset of this Address it was stated that physical theories which lie beyond experience are derived by a process of abstraction from experience. It is instructive to note from this point of view the successive introduction of new conceptions. The idea of the attraction of gravitation was preceded by the observation of the attraction of iron by a magnet, and of light bodies by rubbed amber. The polarity of magnetism and electricity also appealed to the senses. It thus became the substratum of the conception that atoms and molecules are endowed with attractive and repellent poles, by the play of which definite forms of crystalline architecture are produced. Thus molecular force becomes *structural.*[1] It required no great boldness of thought to extend its play into organic nature, and to recognise in molecular force the agency by which both plants and animals are built up. In this way, out of experience arise conceptions which are wholly ultra-experiential. None of the atomists of antiquity had any notion of this play of molecular polar force, but they had experience of gravity, as manifested by falling bodies. Abstracting from this, they permitted their atoms to fall eternally through empty space. Democritus assumed that the larger atoms moved more rapidly than the smaller ones, which they therefore could overtake, and with which they could combine. Epicurus, holding that empty space could offer no resistance to motion, ascribed to all the atoms the same velocity; but he seems to have overlooked the consequence that under such circumstances the atoms could never combine. Lucretius cut the knot by quitting the domain of physics altogether, and causing the atoms to move together by a kind of volition.

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[1] See Art. on Matter and Force, or 'Lectures on Light,' No. III.

Was the instinct utterly at fault which caused Lucretius thus to swerve from his own principles? Diminishing gradually the number of progenitors, Mr. Darwin comes at length to one 'primordial form;' but he does not say, so far as I remember, how he supposes this form to have been introduced. He quotes with satisfaction the words of a celebrated author and divine who had 'gradually learnt to see that it was just as noble a conception of the Deity to believe He created a few original forms, capable of self-development into other and needful forms, as to believe He required a fresh act of creation to supply the voids caused by the action of His laws.' What Mr. Darwin thinks of this view of the introduction of life, I do not know. But the anthropomorphism, which it seemed his object to set aside, is as firmly associated with the creation of a few forms as with the creation of a multitude. We need clearness and thoroughness here. Two courses and two only are possible. Either let us open our doors freely to the conception of creative acts, or abandoning them, let us radically change our notions of Matter. If we look at matter as pictured by Democritus, and as defined for generations in our scientific text-books, the notion of conscious life coming out of it cannot be formed by the mind. The argument placed in the mouth of Bishop Butler suffices, in my opinion, to crush all such materialism as this. Those, however, who framed these definitions of matter were but partial students. They were not biologists, but mathematicians, whose labours referred only to such accidents and properties of matter as could be expressed in their formulæ. Their science was mechanical science, not the science of life. With matter in its wholeness they never dealt; and, denuded by their imperfect definitions, 'the gentle mother of all' became the object of her children's dread. Let us reverently, but honestly, look the question in the face. Divorced from matter, where is life? Whatever our *faith* may say, our *knowledge* shows them to be indissolubly joined. Every meal we eat, and every cup we drink, illustrates the mysterious control of Mind by Matter.

On tracing the line of life backwards, we see it approaching more and more to what we call the purely physical condition. We come at length to those organisms which I have compared to drops of oil suspended in a mixture of alcohol and water. We reach the *protogenes* of Haeckel, in which we have 'a type distinguishable from a fragment of albumen only by its finely granular character.' Can we pause here? We break a magnet, and find two poles in each of its fragments. We continue the process of breaking; but, however small the parts, each carries with it, though enfeebled, the polarity of the whole. And when we can break no longer, we prolong the intellectual vision to the polar molecules. Are we not urged to do *something* similar in the case of life? Is there not a temptation to close to some extent with Lucretius, when he affirms that 'Nature is seen to do all things spontaneously of herself without the meddling of the gods?' or with Bruno, when he declares that Matter is not 'that mere empty *capacity* which philosophers have pictured her to be, but the universal mother who brings forth all things as the fruit of her own womb?' Believing, as I do, in the continuity of nature, I cannot stop abruptly where our microscopes cease to be of use. Here the vision of the mind authoritatively supplements the vision of the eye. By a necessity engendered and justified by science I cross the boundary of the experimental evidence,[1] and discern in that Matter which we, in our ignorance of its latent powers, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of all terrestrial Life.

If you ask me whether there exists the least evidence to prove that any form of life can be developed out of matter, without demonstrable antecedent life, my reply is that evidence considered perfectly conclusive by many has been adduced; and that were some of us who have pondered this question to follow a very common example, and accept testimony because it falls in with our belief, we also should eagerly close with the evidence referred to. But there is in the true man of science a desire stronger than the wish to have his beliefs upheld; namely, the desire to have them true. And this stronger wish causes him to reject the most plausible support, if he has reason to suspect that it is vitiated by error. Those to whom I refer as having studied this question, believing the evidence offered in favour of 'spontaneous generation' to be thus vitiated, cannot accept it. They know full well that the chemist now prepares from inorganic matter a vast array of substances, which were some time ago regarded as the sole products of vitality. They are intimately acquainted with the structural power of matter, as evidenced in the phenomena of crystallisation. They can justify scientifically their *belief* in its potency, under the proper conditions, to produce organisms. But, in reply to your question, they will frankly admit their inability to point to any satisfactory experimental proof that life can be developed, save from demonstrable antecedent life. As already indicated, they draw the line from the highest organisms through lower ones down to the lowest; and it is the prolongation of this line by the intellect, beyond the range of the senses, that leads them to the conclusion which Bruno so boldly enunciated.[1]

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[1] This mode of procedure was not invented in Belfast.

The 'materialism' here professed may be vastly different from what you suppose, and I therefore crave your gracious patience to the end. 'The question of an external world,' says J. S. Mill, 'is the great battle-ground of metaphysics.'[2] Mr. Mill himself reduces external phenomena to 'possibilities of sensation.' Kant, as we have seen, made time and space 'forms' of our own intuitions. Fichte, having first by the inexorable logic of his understanding proved himself to be a mere link in that chain of eternal causation which holds so rigidly in nature, violently broke the chain by making nature, and all that it inherits, an apparition of the mind.[3] And it is by no means easy to combat such notions. For when I say 'I see you,' and that there is not the least doubt about it, the obvious reply is, that what I am really conscious of is an affection of my own retina. And if I urge that my sight can be checked by touching you, the retort would be that I am equally transgressing the limits of fact; for what I am really conscious of is, not that you are there, but that the nerves of my hand have undergone a change. All we hear, and see, and touch, and taste, and smell, are, it would be urged, mere variations of our own condition, beyond which, even to the extent of a hair's breadth, we cannot go. That anything answering to our impressions exists outside of ourselves is not a *fact*, but an *inference*, to which all validity would be denied by an idealist like Berkeley, or by a sceptic like Hume. Mr. Spencer takes another line. With him, as with the uneducated man, there is no doubt or question as to the existence of an external world. But he differs from the uneducated, who think that the world really *is* what consciousness represents it to be. Our states of consciousness are mere *symbols* of an outside entity which produces them and determines the order of their succession, but the real nature of which we can never know.[1] In fact, the whole process of evolution is the manifestation of a Power absolutely inscrutable to the intellect of man. As little in our day as in the days of Job can man by searching find this Power out. Considered fundamentally, then, it is by the operation of an insoluble mystery that life on earth is evolved, species differentiated, and mind unfolded, from their prepotent elements in the immeasurable past.

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[1] Bruno was a 'Pantheist,' not an 'Atheist' or a 'Materialist.'

[2] 'Examination of Hamilton,' p. 154.

[3] 'Bestimmung des Menschen.'

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[1] In a paper, at once popular and profound, entitled 'Recent Progress in the Theory of Vision,' contained in the volume of lectures by Helmholtz, published by Longmans, this symbolism of our states of consciousness is also dwelt upon. The impressions of sense are the mere *signs* of external things. In this paper Helmholtz contends strongly against the view that the consciousness of space is inborn; and he evidently doubts the power of the chick to pick up grains of corn without preliminary lessons. On this point, he says, further experiments are needed. Such experiments have been since made by Mr. Spalding, aided, I believe, in some of his observations by the accomplished and deeply lamented Lady Amberly; and they seem to prove conclusively that the chick does not need a single moment's tuition to enable it to stand, run, govern the muscles of its eyes, and peck. Helmholtz, however, is contending against the notion of pre-established harmony; and I am not aware of his views as to the organisation of experiences of race or breed.

The strength of the doctrine of Evolution consists, not in an experimental demonstration (for the subject is hardly accessible to this mode of proof), but in its general harmony with scientific thought. From contrast, moreover, it derives enormous relative cogency. On the one side we have a theory (if it could with any propriety be so called) derived, as were the theories referred to at the beginning of this Address, not from the study of nature, but from the observation of men—a theory which converts the Power whose garment is seen in the visible universe into an Artificer, fashioned after the human model, and acting by broken efforts as man is seen to act. On the other side we have the conception that all we see around us, and all we feel within us—the phenomena of physical nature as well as those of the human mind—have their unsearchable roots in a cosmical life, if I dare apply the term, an infinitesimal span of which is offered to the investigation of man. And even this span is only knowable in part. We can trace the development of a nervous system, and correlate with it the parallel phenomena of sensation and thought. We see with undoubting certainty that they go hand in hand. But we try to soar in a vacuum the moment we seek to comprehend the connection between them. An Archimedean fulcrum is here required which the human mind cannot command; and the effort to solve the problem—to borrow a comparison from an illustrious friend of mine—is like that of a man trying to lift himself by his own waistband. All that has been said in this discourse is to be taken in connection with this fundamental truth.

When 'nascent senses' are spoken of, when 'the differentiation of a tissue at first vaguely sensitive all over' is spoken of, and when these possessions and processes are associated with 'the modification of an organism by its environment,' the same parallelism, without contact, or even approach to contact, is implied. Man the *object* is separated by an impassable gulf from man the *subject*. There is no motor energy in the human intellect to carry it, without logical rupture, from the one to the other.

§ 9.

The doctrine of Evolution derives man, in his totality, from the interaction of organism and environment through countless ages past. The Human Understanding, for example,—that faculty which Mr. Spencer has turned so skilfully round upon its own antecedents —is itself a result of the play between organism and environment through cosmic ranges of time. Never, surely, did prescription plead so irresistible a claim. But then it comes to pass that, over and above his understanding, there are many other things appertaining to man, whose prescriptive rights are quite as strong as those of the understanding itself. It is a result, for example, of the play of organism and environment that sugar is sweet, and that aloes are bitter; that the smell of henbane differs from the perfume of a rose. Such facts of consciousness (for which, by the way, no adequate reason has ever been rendered) are quite as old as the understanding; and many other things can boast an equally ancient origin. Mr. Spencer at one place refers to that most powerful of passions—the amatory passion—as one which, when it first occurs, is antecedent to all relative experience whatever; and we may press its claim as being at least as ancient, and as valid, as that of the understanding itself. Then there are such things woven into the texture of man as the feeling of Awe, Reverence, Wonder—and not alone the sexual love just referred to, but the love of the beautiful, physical, and moral, in Nature, Poetry, and Art. There is also that deep-set feeling, which, since the earliest dawn of history, and probably for ages prior to all history, incorporated itself in the Religions of the world. You, who have escaped from these religions into the high-and-dry light of the intellect, may deride them; but in so doing you deride accidents of form merely, and fail to touch the immovable basis of the religious sentiment in the nature of man. To yield this sentiment reasonable satisfaction is the problem of problems at the present hour. And grotesque in relation to scientific culture as many of the religions of the world have been and are—dangerous, nay, destructive, to the dearest privileges of freemen as some of them undoubtedly have been, and would, if they could, be again—it will be wise to recognise them as the forms of a force, mischievous if permitted to intrude on the region of objective *knowledge*, over which it holds no command, but capable of adding, in the region of *poetry* and *emotion*, inward completeness and dignity to man.

Feeling, I say again, dates from as old an origin and as high a source as intelligence, and it equally demands its range of play. The wise teacher of humanity will recognise the necessity of meeting this demand, rather than of resisting it on account of errors and absurdities of form. What we should resist, at all hazards, is the attempt made in the past, and now repeated, to found upon this elemental bias of man's nature a system which should exercise despotic sway over his intellect. I have no fear of such a consummation. Science has already to some extent leavened the world; it will leaven it more and more I should look upon the mild light of science breaking in upon the minds of the youth of Ireland, and strengthening gradually to the perfect day, as a surer check to any intellectual or spiritual tyranny which may threaten this island, than the laws of princes or the swords of emperors. We fought and won our battle even in the Middle Ages: should we doubt the issue of another conflict with our broken foe?

The impregnable position of science may be described in a few words. We claim, and we shall wrest from theology, the entire domain of cosmological theory. All schemes and systems which thus infringe upon the domain of science must, in so far as they do this, submit to its control, and relinquish all thought of controlling it. Acting otherwise proved always disastrous in the past, and it is simply fatuous to-day. Every system which would escape the fate of an organism too rigid to adjust itself to its environment, must be plastic to the extent that the growth of knowledge demands. When this truth has been thoroughly taken in, rigidity will be relaxed, exclusiveness diminished, things now deemed essential will be dropped, and elements now rejected will be assimilated. The lifting of the life is the essential point; and as long as dogmatism, fanaticism, and intolerance are kept out, various modes of leverage may be employed to raise life to a higher level.

Science itself not unfrequently derives motive power from an ultra-scientific source. Some of its greatest discoveries have been made under the stimulus of a non-scientific ideal. This was the case among the ancients, and it has been so amongst ourselves. Mayer, Joule, and Colding, whose names are associated with the greatest of modern generalisations, were thus influenced. With his usual insight, Lange at one place remarks, that 'it is not always the objectively correct and intelligible that helps man most, or leads most quickly to the fullest and truest knowledge. As the sliding body upon the brachystochrone reaches its end sooner than by the straighter road of the inclined plane, so, through the swing of the ideal, we often arrive at the naked truth more rapidly than by the processes of the understanding.' Whewell speaks of enthusiasm of temper as a hindrance to science; but he means the enthusiasm of weak heads. There is a strong and resolute enthusiasm in which science finds an ally; and it is to the lowering of this fire, rather than to the diminution of intellectual insight, that the lessening productiveness of men of science, in their mature years, is to be ascribed. Mr. Buckle sought to detach intellectual achievement from moral force. He gravely erred, for without moral force to whip it into action, the achievement of the intellect would be poor indeed.

It has been said by its opponents that science divorces itself from literature; but the statement, like so many others, arises from lack of knowledge. A glance at the less technical writings of its leaders—of its Helmholtz, its Huxley, and its Du Bois-Reymond—would show what breadth of literary culture they command. Where among modern writers can you find their superiors in clearness and vigour of literary style? Science desires not isolation, but freely combines with every effort towards the bettering of man's estate. Single-handed, and supported, not by outward sympathy, but by inward force, it has built at least one great wing of the many-mansioned home which man in his totality demands. And if rough walls and protruding rafter-ends indicate that on one side the edifice is still incomplete, it is only by wise combination of the parts required, with those already irrevocably built, that we can hope for completeness. There is no necessary incongruity between what has been accomplished and what remains to be done. The moral glow of Socrates, which we all feel by ignition, has in it nothing incompatible with the physics of Anaxagoras which he so much scorned, but which he would hardly scorn to-day. And here I am reminded of one among us, hoary, but still strong, whose prophet-voice some thirty years ago, far more than any other of this age, unlocked whatever of life and nobleness lay latent in its most gifted minds --one fit to stand beside Socrates or the Maccabean Eleazar, and to dare and suffer all that they suffered and dared—fit, as he once said of Fichte, 'to have been the teacher of the Stoa, and to have discoursed of Beauty and Virtue in the groves of Academe.' With a capacity to grasp physical principles which his friend Goethe did not possess, and which even total lack of exercise has not been able to reduce to atrophy, it is the world's loss that he, in the vigour of his years, did not open his mind and sympathies to science, and make its conclusions a portion of his message to mankind. Marvellously endowed as he was—equally equipped on the side of the Heart and of the Understanding—he might have done much towards teaching us how to reconcile the claims of both, and to enable them in coming times to dwell together, in unity of spirit and in the bond of peace.

And now the end is come. With more time, or greater strength and knowledge, what has been here said might have been better said, while worthy matters, here omitted, might have received fit expression. But there would have been no material deviation from the views set forth. As regards myself, they are not the growth of a day; and as regards you, I thought you ought to know the environment which, with or without your consent, is rapidly surrounding you, and in relation to which some adjustment on your part may be necessary. A hint of Hamlet's, however, teaches us how the troubles of common life may be ended; and it is perfectly possible for you and me to purchase intellectual peace at the price of intellectual death. The world is not without refuges of this description; nor is it wanting in persons who seek their shelter, and try to persuade others to do the same. The unstable and the weak have yielded and will yield to this persuasion, and they to whom repose is sweeter than the truth. But I would exhort you to refuse the offered shelter, and to scorn the base repose—to accept, if the choice be forced upon you, commotion before stagnation, the breezy leap of the torrent before the fœtid stillness of the swamp. In the course of this Address I have touched on debatable questions, and led you over what will be deemed dangerous ground—and this partly with the view of telling you that, as regards these questions, science claims unrestricted right of search. It is not to the point to say that the views of Lucretius and Bruno, of Darwin and Spencer, may be wrong. Here I should agree with you, deeming it indeed certain that these views will undergo modification. But the point is, that, whether right or wrong, we claim the right to discuss them. For science, however, no exclusive claim is here made; you are not urged to erect it into an idol. The inexorable advance of man's understanding in the path of knowledge, and those unquenchable claims of his moral and emotional nature, which the understanding can never satisfy, are here equally set forth. The world embraces not only a Newton, but a Shakspeare—not only a Boyle, but a Raphael—not only a Kant, but a Beethoven—not only a Darwin, but a Carlyle. Not in each of these, but in all, is human nature whole. They are not opposed, but supplementary—not mutually exclusive, but reconcilable. And if, unsatisfied with them all, the human mind, with the yearning of a pilgrim for his distant home, will still turn to the Mystery from which it has emerged, seeking so to fashion it as to give unity to thought and faith; so long as this is done, not only without intolerance or bigotry of any kind, but with the enlightened recognition that ultimate fixity of conception is here unattainable, and that each succeeding age must be held free to fashion the mystery in accordance with its own needs—then, casting aside all the restrictions of Materialism, I would affirm this to be a field for the noblest exercise of what, in contrast with the *knowing* faculties, may be called the *creative* faculties of man. Here, however, I touch a theme too great for me to handle, but which will assuredly be handled by the loftiest minds, when you and I, like streaks of morning cloud, shall have melted into the infinite azure of the past.

X.

APOLOGY FOR THE BELFAST ADDRESS.

1874.

THE world has been frequently informed of late that I have raised up against myself a host of enemies; and considering, with few exceptions, the deliverances of the Press, and more particularly of the religious Press, I am forced to admit that the statement is only too true. I derive some comfort, nevertheless, from the reflection of Diogenes, transmitted to us by Plutarch, that 'he who would be saved must have good friends or violent enemies; and that he is best off who possesses both.' This 'best' condition, I have reason to believe, is mine.

Reflecting on the fraction I have read of recent remonstrances, appeals, menaces, and judgments—covering not only the world that now is, but that which is to come—I have noticed with mournful interest how trivially men seem to be influenced by what they call their religion, and how potently by that 'nature' which it is the alleged province of religion to eradicate or subdue. From fair and manly argument, from the tenderest and holiest sympathy on the part of those who desire my eternal good, I pass by many gradations, through deliberate unfairness, to a spirit of bitterness, which desires with a fervour inexpressible in words my eternal ill. Now, were religion the potent factor, we might expect a homogeneous utterance from those professing a common creed, while, if human nature be the really potent factor, we may expect utterances as heterogeneous as the characters of men. As a matter of fact we have the latter; suggesting to my mind that the common religion, professed and defended by these different people, is merely the accidental conduit through which they pour their own tempers, lofty or low, courteous or vulgar, mild or ferocious, as the case may be. Pure abuse, however, as serving no good end, I have, wherever possible, deliberately avoided reading, wishing, indeed, to keep, not only hatred, malice, and uncharitableness, but even every trace of irritation, far away from my side of a discussion which demands not only good-temper, but largeness, clearness, and many-sidedness of mind, if it is to guide us to even provisional solutions.

It has been stated, with many variations of note and comment, that in the Address as subsequently published by Messrs. Longman I have retracted opinions uttered at Belfast. A Roman Catholic writer is specially strong upon this point. Startled by the deep chorus of dissent which my 'dazzling fallacies' have evoked, I am now trying to retreat. This he will by no means tolerate. 'It is too late now to seek to hide from the eyes of mankind one foul blot, one ghastly deformity. Professor Tyndall has himself told us how and where this Address of his was composed. It was written among the glaciers and the solitudes of the Swiss mountains. It was no hasty, hurried, crude production; its every sentence bore marks of thought and care.'

My critic intends to be severe: he is simply just. In the 'solitudes' to which he refers I worked with deliberation, endeavouring even to purify my intellect by disciplines similar to those enjoined by his own Church for the sanctification of the soul. I tried, moreover, in my ponderings to realise not only the lawful, but the expedient; and to permit no fear to act upon my mind, save that of uttering a single word on which I could not take my stand, either in this or in any other world.

Still my time was so brief, the difficulties arising from my isolated position were so numerous, and my thought and expression so slow, that, in a literary point of view, I halted, not only behind the ideal, but behind the possible. Hence, after the delivery of the Address, I went over it with the desire, not to revoke its principles, but to improve it verbally, and above all to remove any word which might give colour to the notion of 'crudeness, hurry, or haste.'

In connection with the charge of Atheism my critic refers to the Preface to the second issue of the Belfast Address: 'Christian men,' I there say, 'are proved by their writings to have their hours of weakness and of doubt, as well as their hours of strength and of conviction; and men like myself share, in their own way, these variations of mood and tense. Were the religious moods of many of my assailants the only alternative ones, I do not know how strong the claims of the doctrine of "Material Atheism" upon my allegiance might be. Probably they would be very strong. But, as it is, I have noticed during years of self-observation that it is not in hours of clearness and vigour that this doctrine commends itself to my mind; that in the presence of stronger and healthier thought it ever dissolves and disappears, as offering no solution of the mystery in which we dwell, and of which we form a part.'

With reference to this honest and reasonable utterance my censor exclaims, 'This is a most remarkable passage. Much as we dislike seasoning polemics with strong words, we assert that this Apology only tends to affix with links of steel to the name of Professor Tyndall, the dread imputation against which he struggles.'

Here we have a very fair example of subjective religious vigour. But my quarrel with such exhibitions is that they do not always represent objective fact. No atheistic reasoning can, I hold, dislodge religion from the human heart. Logic cannot deprive us of life, and religion is life to the religious. As an experience of consciousness it is beyond the assaults of logic. But the religious life is often projected in external forms—I use the word in its widest sense—and this embodiment of the religious sentiment will have to bear more and more, as the world become more enlightened, the stress of scientific tests. We must be careful of projecting into external nature that which belongs to ourselves. My critic commits this mistake: he feels, and takes delight in feeling, that I am struggling, and he obviously experiences the most exquisite pleasures of 'the muscular sense' in holding me down. His feelings are as real, as if his imagination of what mine are were equally real. His picture of my 'struggles' is, however, a mere delusion. I do not struggle. I do not fear the charge of Atheism; nor should I even disavow it, in reference to any definition of the Supreme which he, or his order, would be likely to frame. His 'links' and his 'steel' and his 'dread imputations' are, therefore, even more unsubstantial than my 'streaks of morning cloud,' and they may be permitted to vanish together.

These minor and more purely personal matters at an end, the weightier allegation remains, that at Belfast I misused my position by quitting the domain of science, and making an unjustifiable raid into the domain of theology. This I fail to see. Laying aside abuse, I hope my accusers will consent to reason with me. Is it not lawful for a scientific man to speculate on the antecedents of the solar system? Did Kant, Laplace, and William Herschel quit their legitimate spheres, when they prolonged the intellectual vision beyond the boundary of experience, and propounded the nebular theory? Accepting that theory as probable, is it not permitted to a scientific man to follow up, in idea, the series of changes associated with the condensation of the nebulæ; to picture the successive detachment of planets and moons, and the relation of all of them to the sun? If I look upon our earth, with its orbital revolution and axial rotation, as one small issue of the process which made the solar system what it is, will any theologian deny my right to entertain and express this theoretic view? Time was when a multitude of theologians would have been found to do so—when that arch-enemy of science which now vaunts its tolerance would have made a speedy end of the man who might venture to publish any opinion of the kind. But, that time, unless the world is caught strangely slumbering, is for ever past.

As regards inorganic nature, then, we may traverse, without let or hindrance, the whole distance which separates the nebulæ from the worlds of to-day. But only a few years ago this now conceded ground of science was theological ground. I could by no means regard this as the final and sufficient concession of theology; and, at Belfast, I thought it not only my right but my duty to state that, as regards the organic world, we must enjoy the freedom which we have already won in regard to the inorganic. I could not discern the shred of a title-deed which gave any man, or any class of men, the right to open the door of one of these worlds to the scientific searcher and to close the other against him. And I considered it frankest, wisest, and in the long run most conducive to permanent peace, to indicate, without evasion or reserve, the ground that belongs to Science, and to which she will assuredly make good her claim.

I have been reminded that an eminent predecessor of mine in the Presidential chair, expressed a totally different view of the Cause of things from that enunciated by me. In doing so he transgressed the bounds of science at least as much as I did; but nobody raised an outcry against him. The freedom he took I claim. And looking at what I must regard as the extravagances of the religious world; at the very inadequate and foolish notions concerning this universe which are entertained by the majority of our authorised religious teachers; at the waste of energy on the part of good men over things unworthy, if I may say it without discourtesy, of the attention of enlightened heathens; the fight about the fripperies of Ritualism, and the verbal quibbles of the Athanasian Creed; the forcing on the public view of Pontigny Pilgrimages; the dating of historic epochs from the definition of the Immaculate Conception; the proclamation of the Divine Glories of the Sacred Heart—standing in the midst of these chimeras, which astound all thinking men, it did not appear to me extravagant to claim the public tolerance for an hour and a half, for the statement of more reasonable views—views more in accordance with the verities which science has brought to light, and which many weary souls would, I thought, welcome with gratification and relief.

But to come to closer quarters. The expression to which the most violent exception has been taken is this: 'Abandoning all disguise, the confession I feel bound to make before you is, that I prolong the vision backward across the boundary of the experimental evidence, and discern in that Matter which we, in our ignorance, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of every form and quality of life.' To call it a 'chorus of dissent,' as my Catholic critic does, is a mild way of describing the storm of opprobrium with which this statement has been assailed. But the first blast of passion being past, I hope I may again ask my opponents to consent to reason. First of all, I am blamed for crossing the boundary of the experimental evidence. This, I reply, is the habitual action of the scientific mind—at least of that portion of it which applies itself to physical investigation. Our theories of light, heat, magnetism, and electricity, all imply the crossing of this boundary. My paper on the 'Scientific Use of the Imagination,' and my 'Lectures on Light,' illustrate this point in the amplest manner; and in the Article entitled 'Matter and Force' in the present volume I have sought, incidentally, to make clear, that in physics the experiential incessantly leads to the ultra-experiential; that out of experience there always grows something finer than mere experience, and that in their different powers of ideal extension consists, for the most part, the difference between the great and the mediocre investigator. The kingdom of science, then, cometh not by observation and experiment alone, but is completed by fixing the roots of observation and experiment in a region inaccessible to both, and in dealing with which we are forced to fall back upon the picturing power of the mind.

Passing the boundary of experience, therefore, does not, in the abstract, constitute a sufficient ground for censure. There must have been something in my particular mode of crossing it which provoked this tremendous 'chorus of dissent.'

Let us calmly reason the point out. I hold the nebular theory as it was held by Kant, Laplace, and William Herschel, and as it is held by the best scientific intellects of to-day. According to it, our sun and planets were once diffused through space as an impalpable haze, out of which, by condensation, came the solar system. What caused the haze to condense? Loss of heat. What rounded the sun and planets? That which rounds a tear—molecular force. For æons, the immensity of which overwhelms man's conceptions, the earth was unfit to maintain what we call life. It is now covered with visible living things. They are not formed of matter different from that of the earth around them. They are, on the contrary, bone of its bone, and flesh of its flesh. How were they introduced? Was life implicated in the nebula—as part, it may be, of a vaster and wholly Unfathomable Life; or is it the work of a Being standing outside the nebula, who fashioned it, and vitalised it; but whose own origin and ways are equally past finding out? As far as the eye of science has hitherto ranged through nature, no intrusion of purely creative power into any series of phenomena has ever been observed. The assumption of such a power to account for special phenomena, though often made, has always proved a failure. It is opposed to the very spirit of science; and I therefore assumed the responsibility of holding up, in contrast with it, that method of nature which it has been the vocation and triumph of science to disclose, and in the application of which we can alone hope for further light. Holding, then, that the nebulæ and the solar system, life included, stand to each other in the relation of the germ to the finished organism, I reaffirm here, not arrogantly, or defiantly, but without a shade of indistinctness, the position laid down at Belfast.

Not with the vagueness belonging to the emotions, but with the definiteness belonging to the understanding, the scientific man has to put to himself these questions regarding the introduction of life upon the earth. He will be the last to dogmatise upon the subject, for he knows best that certainty is here for the present unattainable. His refusal of the creative hypothesis is less an assertion of knowledge than a protest against the assumption of knowledge which must long, if not for ever, lie beyond us, and the claim to which is the source of perpetual confusion upon earth. With a mind open to conviction he asks his opponents to show him an authority for the belief they so strenuously and so fiercely uphold. They can do no more than point to the Book of Genesis, or some other portion of the Bible. Profoundly interesting, and indeed pathetic, to me are those attempts of the opening mind of. man to appease its hunger for a Cause. But the Book of Genesis has no voice in scientific questions. To the grasp of geology, which it resisted for a time, it at length yielded like potter's clay; its authority as a system of cosmogony being discredited on all hands, by the abandonment of the obvious meaning of its writer. It is a poem, not a scientific treatise. In the former aspect it is for ever beautiful: in the latter aspect it has been, and it will continue to be, purely obstructive and hurtful. To *knowledge* its value has been negative, leading, in rougher ages than ours, to physical, and even in our own 'free' age to moral, violence.

No incident connected with the proceedings at Belfast is more instructive than the deportment of the Catholic hierarchy of Ireland; a body usually too wise to confer notoriety upon an adversary by imprudently denouncing him. The 'Times,' to which I owe a great deal on the score of fair play, where so much has been unfair, thinks that the Irish Cardinal, Archbishops, and Bishops, in a recent manifesto, adroitly employed a weapon which I, at an unlucky moment, placed in their hands. The antecedents of their action cause me to regard it in a different light; and a brief reference to these antecedents will, I think, illuminate not only their proceedings regarding Belfast, but other doings which have been recently noised abroad.

Before me lies a document bearing the date of November 1873, which, after appearing for a moment, unaccountably vanished from public view. It is a Memorial addressed, by Seventy of the Students and Ex-students of the Catholic University in Ireland, to the Episcopal Board of the University; and it constitutes the plainest and bravest remonstrance ever addressed by Irish laymen to their spiritual pastors and masters. It expresses the profoundest dissatisfaction with the curriculum marked out for the students of the University; setting forth the extraordinary fact that the lecture-list for the faculty of Science, published a month before they wrote, did not contain the name of a single Professor of the Physical or Natural Sciences.

The memorialists forcibly deprecate this, and dwell upon the necessity of education in science: 'The distinguishing mark of this age is its ardour for science. The natural sciences have, within the last fifty years, become the chiefest study in the world; they are in our time pursued with an activity unparalleled in the history of mankind. Scarce a year now passes without some discovery being made in these sciences which, as with the touch of the magician's wand, shivers to atoms theories formerly deemed unassailable. It is through the physical and natural sciences that the fiercest assaults are now made on our religion. No more deadly weapon is used against our faith than the facts incontestably proved by modern researches in science.'

Such statements must be the reverse of comfortable to a number of gentlemen who, trained in the philosophy of Thomas Aquinas, have been accustomed to the unquestioning submission of all other sciences to their divine science of Theology. But this is not all: 'One thing seems certain,' say the memorialists, viz., 'that if chairs for the physical and natural sciences be not soon founded in the Catholic University, very many young men will have their faith exposed to dangers which the creation of a school of science in the University would defend them from. For our generation of Irish Catholics are writhing under the sense of their inferiority in science, and are determined that such inferiority shall not long continue; and so, if scientific training be unattainable at our University, they will seek it at Trinity or at the Queen's Colleges, in not one of which is there a Catholic Professor of Science.'

Those who imagined the Catholic University at Kensington to be due to the spontaneous recognition, on the part of the Roman hierarchy, of the intellectual needs of the age, will derive enlightenment from this, and still more from what follows: for the most formidable threat remains. To the picture of Catholic students seceding to Trinity and the Queen's Colleges, the memorialists add this darkest stroke of all: 'They will, in the solitude of their own homes, unaided by any guiding advice, devour the works of Haeckel, Darwin, Huxley, Tyndall, and Lyell; works innocuous if studied under a professor who would point out the difference between established facts and erroneous inferences, but which are calculated to sap the faith of a solitary student, deprived of a discriminating judgment to which he could refer for a solution of his difficulties.'

In the light of the knowledge given by this courageous memorial, and of similar knowledge otherwise derived, the recent Catholic manifesto did not at all strike me as a chuckle over the mistake of a maladroit adversary, but rather as an evidence of profound uneasiness on the part of the Cardinal, the Archbishops, and the Bishops who signed it. They acted towards the Students' Memorial, however, with their accustomed practical wisdom. As one concession to the spirit which it embodied, the Catholic University at Kensington was brought forth, apparently as the effect of spontaneous inward force, and not of outward pressure becoming too formidable to be successfully opposed.

The memorialists point with bitterness to the fact, that 'the name of no Irish Catholic is known in connection with the physical and natural sciences.' But this, they ought to know, is the complaint of free and cultivated minds wherever a Priesthood exercises dominant power. Precisely the same complaint has been made with respect to the Catholics of Germany. The great national literature and the scientific achievements of that country, in modern times, are almost wholly the work of Protestants. A vanishingly small fraction of it only is derived from members of the Roman Church, although the number of these in Germany is at least as great as that of the Protestants. 'The question arises,' says a writer in an able German periodical, 'what is the cause of a phenomenon so humiliating to the Catholics? It cannot be referred to want of natural endowment due to climate (for the Protestants of Southern Germany have contributed powerfully to the creations of the German intellect), but purely to outward circumstances. And these are readily discovered in the pressure exercised for centuries by the Jesuitical system, which has crushed out of Catholics every tendency to free mental productiveness.' It is, indeed, in Catholic countries that the weight of Ultramontanism has been most severely felt. It is in such countries that the very finest spirits, who have dared, without quitting their faith, to plead for freedom or reform, have suffered extinction. The extinction, however, was more apparent than real, and Hermes, Hirscher, and Günther, though individually broken and subdued, prepared the way, in Bavaria, for the persecuted but unflinching Frohschammer, for Döllinger, and for the remarkable liberal movement of which Döllinger is the head and guide.

Though moulded for centuries to an obedience unparalleled in any other country, except Spain, the Irish intellect is beginning to show signs of independence; demanding a diet more suited to its years than the pabulum of the Middle Ages. As for the recent manifesto in which Pope, Cardinal, Archbishops, and Bishops are united in one grand anathema, its character and fate are shadowed forth by the Vision of Nebuchadnezzar recorded in the Book of Daniel. It resembles the image, whose form was terrible, but the gold, and silver, and brass, and iron of which rested upon feet of clay. And a stone smote the feet of clay; and the iron, and the brass, and the silver, and the gold, were broken in pieces together, and became like the chaff of the summer threshing-floors, and the wind carried them away.

Monsignor Capel has recently been good enough to proclaim at once the friendliness of his Church towards true science, and her right to determine what true science is. Let us dwell for a moment on the proofs of her scientific competence. When Halley's comet appeared in 1456 it was regarded as the harbinger of God's vengeance, the dispenser of war, pestilence, and famine, and by order of the Pope the church bells of Europe were rung to scare the monster away. An additional daily prayer was added to the supplications of the faithful. The comet in due time disappeared, and the faithful were comforted by the assurance that, as in previous instances relating to eclipses, droughts, and rains, so also as regards this 'nefarious' comet, victory had been vouchsafed to the Church.

Both Pythagoras and Copernicus had taught the heliocentric doctrine—that the earth revolves round the sun. In the exercise of her right to determine what true science is, the Church, in the Pontificate of Paul V., stepped in, and by the mouth of the holy Congregation of the Index, delivered, on March 5, 1616, the following decree :--

And whereas it hath also come to the knowledge of the said holy congregation that the false Pythagorean doctrine of the mobility of the earth and the immobility of the sun, entirely opposed to Holy writ, which is taught by Nicolas Copernicus, is now published abroad and received by many. In order that this opinion may not further spread, to the damage of Catholic truth, it is ordered that this and all other books teaching the like doctrine be suspended, and by this decree they are all respectively suspended, forbidden, and condemned.

But why go back to 1456 and 1616? Far be it from me to charge bygone sins upon Monsignor Capel, were it not for the practices he upholds to-day. The most applauded dogmatist and champion of the Jesuits is, I am informed, Perrone. No less than thirty editions of a work of his have been scattered abroad for the healing of the nations. His notions of physical astronomy are virtually those of 1456. He teaches boldly that 'God does not rule by universal law . . . that when God orders a given planet to stand still He does not detract from any law passed by Himself, but orders that planet to move round the sun for such and such a time, then to stand still, and then again to move, as His pleasure may be.' Jesuitism proscribed Frohschammer for questioning its favourite dogma, that every human soul was created by a direct supernatural act of God, and for asserting that man, body and soul, came from his parents. This is the system that now strives for universal power; it is from it, as Monsignor Capel graciously informs us, that we are to learn what is allowable in science, and what is not!

In the face of such facts, which might be multiplied at will, it requires extraordinary bravery of mind, or a reliance upon public ignorance almost as extraordinary, to make the claims made by Monsignor Capel for his Church.

Before me is a very remarkable letter addressed in 1875 by the Bishop of Montpellier to the Deans and Professors of Faculties of Montpellier, in which the writer very clearly lays down the claims of his Church. He had been startled by an incident occurring in a course of lectures on Physiology given by a professor, of whose scientific capacity there was no doubt, but who, it was alleged, rightly or wrongly, had made his course the vehicle of materialism. 'Je ne me suis point donné,' says the Bishop, 'la mission que je remplis au milieu de vous. "Personne, au temoignage de saint Paul, ne s'attribue à soi-même un pareil honneur; il y faut être appelé de Dieu, comme Aaron." Et pourquoi en est-il ainsi? C'est parce que, selon le même Apôtre, nous devons être les ambassadeurs de Dieu; et il n'est pas dans les usages, pas plus qu'il n'est dans la raison et le droit, qu'un envoyé s'accrédite lui-meme. Mais, si j'ai reçu

d'En-Haut une mission; si l'Eglise, au nom de Dieu lui-même, a souscrit mes lettres de créance, me siérait-il de manquer aux instructions qu'elle m'a données et d'entendre, en un sens différent du sien, le rôle qu'elle m'a confié ?

'Or, Messieurs, la sainte Eglise se croit investie du droit absolu d'enseigner les hommes; elle se croit dépositaire de la vérité, non pas de la vérité fragmentaire, incomplète, mêlée de certitude et d'hésitation, mais de la vérité totale, complète, au point de vue religieux. Bien plus, elle est si sûre de l'infaillibilité que son Fondateur divin lui a communiquée, comme la dot magnifique de leur indissoluble alliance, que, même dans l'ordre naturel, scientifique ou philosophique, moral ou politique, elle n'admet pas qu'un système puisse être soutenu et adopté par des chrétiens, s'il contredit à des dogmes définis. Elle considère que la négation volontaire et opiniâtre d'un seul point de sa doctrine rend coupable du péché d'hérésie; et elle pense que toute hérésie formelle, si on ne la rejette pas courageusement avant de paraître devant Dieu, entraîne avec soi la perte certaine de la grâce et de l'éternité.'

The Bishop recalls those whom he addresses from the false philosophy of the present to the philosophy of the past, and foresees the triumph of the latter. 'Avant que le dix-neuvième siècle s'achève, la vieille philosophie scolastique aura repris sa place dans la juste admiration du monde. Il lui faudra pourtant bien du temps pour guérir les maux de tout genre, causés par son indigne rivale; et pendant de longues années encore, ce nom de *philosophie*, le plus grand de la langue humaine après celui de *religion*, sera suspect aux âmes qui se souviendront de la science impie et matérialiste de Locke, de Condillac ou d'Helvétius. L'heure actuelle est aux sciences naturelles : c'est maintenant l'instrument

de combat contre l'Eglise et contre toute foi religieuse. Nous ne les redoutons pas.' Further on the Bishop warns his readers that everything can be abused. Poetry is good, but in excess it may injure practical conduct. 'Les mathématiques sont excellentes : et Bossuet les a louées "comme étant ce qui sert le plus à la justesse du raisonnement;" mais si on s'accoutume exclusivement à leur méthode, rien de ce qui appartient à l'ordre moral ne paraît plus pouvoir être démontré ; et Fénelon a pu parler de *l'ensorcellement* et des attraits *diaboliques* de la géométrie.'

The learned Bishop thus finally accentuates the claims of the Church :—'Comme le définissait le Pape Léon X, au cinquième concile œcuménique de Latran, "Le vrai ne peut pas être contraire à lui-même : par conséquent, toute assertion contraire à une vérité de foi révélée est nécessairement et absolument fausse." Il suit de là que, sans entrer dans l'examen scientifique de telle ou telle question de physiologie, mais par la seule certitude de nos dogmes, nous pouvons juger du sort de telle ou telle hypothèse, qui est une machine de guerre anti-chrétienne plutôt qu'une conquête sérieuse sur les secrets et les mystères de la nature. . . . C'est un dogme que l'homme a été formé et façonné des mains de Dieu. Donc il est faux, hérétique, contraire à la dignité du Créateur et offensant pour son chef-d'œuvre, de dire que l'homme constitue la *septième* espèce des singes . . . . Hérésie encore de dire que le genre humain n'est pas sorti d'un seul couple, et qu'on y peut compter jusqu'à *douze* races distinctes !'

The course of life upon earth, as far as Science can see, has been one of amelioration—a steady advance on the whole from the lower to the higher. The continued effort of animated nature is to improve its condition and raise itself to a loftier level. In man improvement and amelioration depend largely upon the growth of conscious knowledge, by which the errors of ignorance are continually moulted, and truth is organised. It is the advance of knowledge that has given a materialistic colour to the philosophy of this age. Materialism is therefore not a thing to be mourned over, but to be honestly considered—accepted if it be wholly true, rejected if it be wholly false, wisely sifted and turned to account if it embrace a mixture of truth and error. Of late years the study of the nervous system, and its relation to thought and feeling, have profoundly occupied enquiring minds. It is our duty not to shirk—it ought rather to be our privilege to accept—the established results of such enquiries, for here assuredly our ultimate weal depends upon our loyalty to the truth. Instructed as to the control which the nervous system exercises over man's moral and intellectual nature, we shall be better prepared, not only to mend their manifold defects, but also to strengthen and purify both. Is mind degraded by this recognition of its dependence? Assuredly not. Matter, on the contrary, is raised to the level it ought to occupy, and from which timid ignorance would remove it.

But the light is dawning, and it will become stronger as time goes on. Even the Brighton "Church Congress" affords evidence of this. From the manifold confusions of that assemblage my memory has rescued two items, which it would fain preserve: the recognition of a relation between Health and Religion, and the address of the Rev. Harry Jones. Out of the conflict of vanities his words emerge wholesome and strong, because undrugged by dogma, coming directly from the warm brain of one who knows what practical truth means, and who has faith in its vitality and inherent power of propagation.

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It is otherwise with Mr. Martineau, and hence his discontent. He professes to *know* where I only claim to *feel*. He could make his contention good against me if, by a process of verification, he would transform his assumptions into 'objective knowledge.' But he makes no attempt to do so. They remain assumptions from the beginning of his Address to its end. And yet he frequently uses the word 'unverified,' as if it were fatal to the position on which its incidence falls. 'The scrutiny of Nature' is one of his sources of 'religious faith:' what logical foothold does that scrutiny furnish, on which any one of the foregoing three assumptions could be planted? Nature, according to his picturing, is base and cruel: what is the inference to be drawn regarding its Author? If Nature be 'red in tooth and claw,' who is responsible? On a Mindless nature Mr. Martineau pours the full torrent of his gorgeous invective; but could the 'assumption' of 'an Eternal Mind'—even of a Beneficent Eternal Mind—render the world objectively a whit less mean and ugly than it is? [illegible] It is man's feelings, and not external phenomena, that are influenced by the assumption. It adds not a ray of light nor a strain of music to the objective sum of things. It does not touch the phenomena of physical nature—storm, flood, or fire—nor diminish by a pang the bloody conflicts of the animal world. But it does add the glow of religious emotion to the human soul, as represented by Mr. Martineau. Beyond this I defy him to go; and yet he rashly—it might be said petulantly—kicks away the only philosophic foundation on which it is possible for him to build his religion.

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I wonder whether he is less effectual in his ministry than his more embroidered colleagues? It surely behoves our teachers to come to some definite understanding as to this question of health; to see how, by inattention to it, we are defrauded, negatively and positively: negatively, by the privation of that 'sweetness and light' which is the natural concomitant of good health; positively, by the insertion into life of cynicism, ill-temper, and a thousand corroding anxieties which good health would dissipate. We fear and scorn 'materialism.' But he who knew all about it, and could apply his knowledge, might become the preacher of a new gospel. Not, however, through the ecstatic moments of the individual does such knowledge come, but through the revelations of science, in connection with the history of mankind.

Why should the Roman Catholic Church call gluttony a mortal sin? Why should fasting occupy a place in the disciplines of religion? What is the meaning of Luther's advice to the young clergyman who came to him, perplexed with the difficulties of predestination and election, if it be not that, in virtue of its action upon the brain, when wisely applied, there is moral and religious virtue even in a hydro-carbon? To use the old language, food and drink are creatures of God, and have therefore a spiritual value. Through our neglect of the monitions of a reasonable materialism we sin and suffer daily. I might here point to the train of deadly disorders over which science has given modern society such control—disclosing the lair of the material enemy, ensuring his destruction, and thus preventing that moral squalor and hopelessness which habitually tread on the heels of epidemics in the case of the poor.

Rising to higher spheres, the visions of Swedenborg, and the ecstasy of Plotinus and Porphyry, are phases of that psychical condition, obviously connected with the nervous system and state of health, on which is based the Vedic doctrine of the absorption of the individual into the universal soul. Plotinus taught the devout how to pass into a condition of ecstasy. Porphyry complains of having been only once united to God in eighty-six years, while his master Plotinus had been so united six times in sixty years.[1] A friend who knew Wordsworth informs me that the poet, in some of his moods, was accustomed to seize hold of an external object to assure himself of his own bodily existence. As states of consciousness such phenomena have an undisputed reality, and a substantial identity; but they are connected with the most heterogeneous objective conceptions. The subjective experiences are similar, because of the similarity of the underlying organisations.

But for those who wish to look beyond the practical facts, there will always remain ample room for speculation. Take the argument of the Lucretian introduced in the Belfast Address. As far as I am aware, not one of my assailants has attempted to answer it. Some of them, indeed, rejoice over the ability displayed by Bishop Butler in rolling back the difficulty on his opponent; and they even imagine that it is the Bishop's own argument that is there employed. But the raising of a new difficulty does not abolish—does not even lessen—the old one, and the argument of the Lucretian remains untouched by anything the Bishop has said or can say.

And here it may be permitted me to add a word to an important controversy now going on: and which turns on the question: Do states of consciousness enter as links into the chain of antecedence and sequence, which give rise to bodily actions, and to other states of consciousness; or are they merely *by-products*, which are not essential to the physical processes going on in the brain? Speaking for myself, it is certain that I have no power of imagining states of consciousness, interposed between the molecules of the brain, and influencing the transference of motion among the molecules. The thought 'eludes all mental presentation;' and hence the logic seems of iron strength which claims for the brain an automatic action, uninfluenced by states of consciousness. But it is, I believe, admitted by those who hold the automaton-theory, that states of consciousness are *produced* by the marshalling of the molecules of the brain: and this production of consciousness by molecular motion is to me quite as inconceivable on mechanical principles as the production of molecular motion by consciousness. If, therefore, I reject one result, I must reject both. I, however, reject neither, and thus stand in the presence of two Incomprehensibles, instead of one Incomprehensible. While accepting fearlessly the facts of materialism dwelt upon in these pages, I bow my head in the dust before that mystery of mind, which has hitherto defied its own penetrative power, and which may ultimately resolve itself into a demonstrable impossibility of self-penetration.

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[1] I recommend to the reader's particular attention Dr. Draper's important work entitled, 'History of the Conflict between Religion and Science' (Messrs. H. S. King and Co.)

But the secret is an open one—the practical monitions are plain enough, which declare that on our dealings with matter depend our weal and woe, physical and moral. The state of mind which rebels against the recognition of the claims of 'materialism' is not unknown to me. I can remember a time when I regarded my body as a weed, so much more highly did I prize the conscious strength and pleasure derived from moral and religious feeling—which, I may add, was mine without the intervention of dogma. The error was not an ignoble one, but this did not save it from the penalty attached to error. Saner knowledge taught me that the body is no weed, and that treated as such it would infallibly avenge itself. Am I personally lowered by this change of front? Not so. Give me their health, and there is no spiritual experience of those earlier years—no resolve of duty, or work of mercy, no work of self-renouncement, no solemnity of thought, no joy in the life and aspects of nature—that would not still be mine; and this without the least reference or regard to any purely personal reward or punishment looming in the future.

And now I have to utter a 'farewell' free from bitterness to all my readers; thanking my friends for a sympathy more steadfast, I would fain believe, if less noisy, than the antipathy of my foes; and commending to these a passage from Bishop Butler, which they have either not read or failed to lay to heart. 'It seems,' saith the Bishop, 'that men would be strangely headstrong and self-willed, and disposed to exert themselves with an impetuosity which would render society insupportable, and the living in it impracticable, were it not for some acquired moderation and self-government, some aptitude and readiness in restraining themselves, and concealing their sense of things.'

XI.

THE REV. JAMES MARTINEAU AND THE BELFAST ADDRESS.[1]

PRIOR to the publication of the Fifth Edition of these 'Fragments' my attention had been directed by several estimable, and indeed eminent, persons, to an essay by the Rev. James Martineau, as demanding serious consideration at my hands. I tried to give the essay the attention claimed for it, and published my views of it as an Introduction to Part II. of the 'Fragments.' I there referred, and here again refer with pleasure, to the accord subsisting between Mr. Martineau and myself on certain points of biblical Cosmogony. 'In so far,' says he, 'as Church belief is still committed to a given Cosmogony and natural history of man, it lies open to scientific refutation.' And again: 'It turns out that with the sun and moon and stars, and in and on the earth, before and after the appearance of our race, quite other things have happened than those which the sacred Cosmogony recites.' Once more: 'The whole history of the genesis of things Religion must surrender to the Sciences.' Finally, still more emphatically: 'In the investigation of the genetic order of things, Theology is an intruder, and must stand aside.' This expresses, only in words of fuller pith, the views which I ventured to enunciate in Belfast. 'The impregnable position of

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[1] 'Fortnightly Review.'

Science,' I there say, 'may be stated in a few words. We claim, and we shall wrest from Theology, the entire domain of Cosmological theory.' Thus Theology, so far as it is represented by Mr. Martineau, and Science, so far as I understand it, are in absolute harmony here.

But Mr. Martineau would have just reason to complain of me, if, by partial citation, I left my readers under the impression that the agreement between us is complete. At the opening of the eighty-ninth Session of the Manchester New College, London, on October 6, 1874, he, its principal, delivered an Address bearing the title 'Religion as affected by Modern Materialism;' the references and general tone of which make evident the depth of its author's discontent with my previous deliverance at Belfast. I find it difficult to grapple with the exact grounds of this discontent. Indeed, logically considered, the impression left upon my mind by an essay of great æsthetic merit, containing many passages of exceeding beauty, and many sentiments which none but the pure in heart could utter as they are uttered here, is vague and unsatisfactory. The author appears at times so brave and liberal, at times so timid and captious, and at times, if I dare say it, so imperfectly informed, regarding the position he assails.

At the outset of his Address Mr. Martineau states with some distinctness his 'sources of religious faith.' They are two—'the scrutiny of Nature' and 'the interpretation of Sacred Books.' It would have been a theme worthy of his intelligence to have deduced from these two sources his religion as it stands. But not another word is said about the 'Sacred Books.' Having swept with the besom of Science various 'books' contemptuously away, he does not define the Sacred residue; much less give us the reasons why he deems them sacred.[1] His references to 'Nature,' on the other hand, are magnificent tirades against Nature, intended, apparently, to show the wholly abominable character of man's antecedents if the theory of evolution be true. Here also his mood lacks steadiness. While joyfully accepting, at one place, 'the widening space, the deepening vistas of time, the detected marvels of physiological structure, and the rapid filling-in of the missing links in the chain of organic life,' he falls, at another, into lamentation and mourning over the very theory which renders 'organic life' 'a chain.' He claims the largest liberality for his sect, and avows its contempt for the dangers of possible discovery. But immediately afterwards he damages the claim, and ruins all confidence in the avowal. He professes sympathy with modern Science, and almost in the same breath he treats, or certainly will be understood to treat, the Atomic Theory, and the doctrine of the Conservation of Energy, as if they were a kind of scientific thimble-riggery.

His ardour, moreover, renders him inaccurate; causing him to see discord between scientific men where nothing but harmony reigns. In his celebrated Address to the Congress of German Naturforscher, delivered at Leipzig, three years ago, Du Bois-Reymond speaks thus: 'What conceivable connection subsists between definite movements of definite atoms in my brain, on the one hand, and on the other hand such primordial, indefinable, undeniable, facts as these: I feel pain or pleasure; I experience a sweet taste, or smell a rose, or hear an organ, or see something red. . . It is absolutely and for ever inconceivable that a number of carbon, hydrogen, nitrogen, and oxygen atoms should be otherwise than indifferent as to their own position and motion, past, present, or future. It is utterly inconceivable how consciousness should result from their joint action.'

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[1] Mr. Martineau's use of the term 'sacred' is unintentionally misleading. In his later essays we are taught that he does not mean to restrict it to the Bible. He does not, however, mention the 'books' beyond those of the Bible to which he would apply the term. 1879.

This language, which was spoken in 1872, Mr. Martineau 'freely' translates, and quotes against me. The act is due to misapprehension. Evidence is at hand to prove that I employed similar language twenty years ago. It is to be found in the 'Saturday Review' for 1860; but a sufficient illustration of the agreement between my friend Du Bois-Reymond and myself, is furnished by the discourse on 'Scientific Materialism,' delivered in 1868, then widely circulated, and reprinted here. The reader who compares the two discourses will see that the same line of thought is pursued in both, and that perfect agreement reigns between my friend and me. In the very Address he criticises, Mr. Martineau might have seen that precisely the same position is maintained. A quotation will prove this :—'Thus far,' I say, 'our way is clear, but now comes my difficulty. Your atoms are individually without sensation, much more are they without intelligence. May I ask you, then, to try your hand upon this problem? Take your dead hydrogen atoms, your dead oxygen atoms, your dead carbon atoms, your dead nitrogen atoms, your dead phosphorus atoms, and all the other atoms, dead as grains of shot, of which the brain is formed. Imagine them separate and sensationless; observe them running together and forming all imaginable combinations. This, as a purely mechanical process, is *seeable* by the mind. But can you see, or dream, or in any way imagine, how out of that mechanical act, and from these individually dead atoms, sensation, thought, and emotion are to rise? Are you likely to extract Homer out of the rattling of dice, or the Differential Calculus out of the clash of billiard balls? . . . I can follow a particle of musk until it reaches the olfactory nerve; I can follow the waves of sound until their tremors reach the water of the labyrinth, and set the otoliths and Corti's fibres in motion; I can also visualise the waves of ether as they cross the eye and hit the retina. Nay, more, I am able to pursue to the central organ the motion thus imparted at the periphery, and to see in idea the very molecules of the brain thrown into tremors. My insight is not baffled by these physical processes. What baffles and bewilders me is the notion that from these physical tremors things so utterly incongruous with them as sensation, thought, and emotion can be derived.' It is only a complete misapprehension of our true relationship that could induce Mr. Martineau to represent Du Bois-Reymond and myself as opposed to each other.

'The affluence of illustration,' writes an able and sympathetic reviewer of this essay, in the 'New York Tribune,' 'in which Mr. Martineau delights often impairs the distinctness of his statements by diverting the attention of the reader from the essential points of his discussion to the beauty of his imagery, and thus diminishes their power of conviction.' To the beauties here referred to I bear willing testimony; but the reviewer is strictly just in his estimate of their effect upon my critic's logic. The 'affluence of illustration,' and the heat, and haze, and haste, generated by its reaction upon Mr. Martineau's own mind, often produce vagueness where precision is the one thing needful —poetic fervour where we require judicial calm; and practical unfairness where the strictest justice ought to be, and I willingly believe is meant to be, observed.

In one of his nobler passages Mr. Martineau tells us how the pupils of his college have been educated hitherto: 'They have been trained under the assumptions (1) that the Universe which includes us and folds us round is the life-dwelling of an Eternal Mind; (2) that the world of our abode is the scene of a moral government, incipient but not complete; and (3) that the upper zones of human affection, above the clouds of self and passion, take us into the sphere of a Divine Communion. Into this over-arching scene it is that growing thought and enthusiasm have expanded to catch their light and fire.'

Alpine summits seem to kindle above us as we read these glowing words; we see their beauty and feel their life. At the close of one of the essays here printed,[1] I thus refer to the 'Communion' which Mr. Martineau calls 'Divine': '"Two things," said Immanuel Kant, "fill me with awe—the starry heavens, and the sense of moral responsibility in man." And in his hours of health and strength and sanity, when the stroke of action has ceased, and the pause of reflection has set in, the scientific investigator finds himself overshadowed by the same awe. Breaking contact with the hampering details of earth, it associates him with a power which gives fulness and tone to his existence, but which he can neither analyse nor comprehend.' Though 'knowledge' is here disavowed, the 'feelings' of Mr. Martineau and myself are, I think, very much alike. He, nevertheless, censures me—almost denounces me—for referring Religion to the region of Emotion. Surely he is inconsistent here. The foregoing words refer to an inward hue or temperature, rather than to an external object of thought. When I attempt to give the Power which I see manifested in the Universe an objective form, personal or otherwise, it slips away from me, declining all intellectual manipulation. I dare not, save poetically, use the pronoun 'He' regarding it; I dare not call it a 'Mind;' I refuse to call it even a 'Cause.' Its mystery overshadows me; but it remains a mystery, while the objective frames which some of my neighbours try to make it fit, seem to me to distort and desecrate it.

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[1] 'Scientific Use of the Imagination.'

It is otherwise with Mr. Martineau, and hence his discontent. He professes to *know* where I only claim to *feel*. He could make his contention good against me if, by a process of verification, he would transform his assumptions into 'objective knowledge.' But he makes no attempt to do so. They remain assumptions from the beginning of his Address to its end. And yet he frequently uses the word 'unverified,' as if it were fatal to the position on which its incidence falls. 'The scrutiny of Nature' is one of his sources of 'religious faith:' what logical foothold does that scrutiny furnish, on which any one of the foregoing three assumptions could be planted? Nature, according to his picturing, is base and cruel: what is the inference to be drawn regarding its Author? If Nature be 'red in tooth and claw,' who is responsible? On a Mindless nature Mr. Martineau pours the full torrent of his gorgeous invective; but could the 'assumption' of 'an Eternal Mind'—even of a Beneficent Eternal Mind—render the world objectively a whit less mean and ugly than it is? Not an iota. It is man's feelings, and not external phenomena, that are influenced by the assumption. It adds not a ray of light nor a strain of music to the objective sum of things. It does not touch the phenomena of physical nature—storm, flood, or fire—nor diminish by a pang the bloody combats of the animal world. But it does add the glow of religious emotion to the human soul, as represented by Mr. Martineau. Beyond this I defy him to go; and yet he rashly—it might be said petulantly—kicks away the only philosophic foundation on which it is possible for him to build his religion.

He twits incidentally the modern scientific interpretation of nature because of its want of cheerfulness. 'Let the new future,' he says, 'preach its own gospel, and devise, if it can, the means of making the tidings *glad*.' This is a common argument: 'If you only knew the comfort of belief!' My reply is that I choose the nobler part of Emerson, when, after various disenchantments, he exclaimed, 'I covet *truth*!' The gladness of true heroism visits the heart of him who is really competent to say this. Besides, 'gladness' is an emotion, and Mr. Martineau theoretically scorns the emotional. I am not, however, acquainted with a writer who draws more largely upon this source, while mistaking it for something objective. 'To reach the Cause,' he says, 'there is no need to go into the past, as though being missed here, He could be found there. But when once He has been apprehended by the proper organs of divine apprehension, the whole life of Humanity is recognised as the scene of His agency.' That Mr. Martineau should have lived so long, thought so much, and failed to recognise the entirely subjective character of this creed, is highly instructive. His 'proper organs of divine apprehension'—given, we must assume, to Mr. Martineau and his pupils, but denied to many of the greatest intellects and noblest men in this and other ages—lie at the very core of his emotions.

In fact, it is when Mr. Martineau is most purely an external object of thought. When I attempt to give the Power which I see manifested in the Universe an objective form, personal or otherwise, it slips away from me, declining all intellectual manipulation. I dare not, save poetically, use the pronoun 'He' regarding it; I dare not call it a 'Mind;' I refuse to call it even a 'Cause.' Its mystery overshadows me; but it remains a mystery, while the objective frames which some of my neighbours try to make it fit, seem to me to distort and desecrate it.

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[1] Address on 'Scientific Materialism.'

cost of its monism [put into it by Mr. Martineau], your scheme seems hardly to gain its end; for by what manipulation of your resources will you, for example, educe Consciousness?"'

This reads like pleasantry, but it deals with serious things. For the last seven years the question here proposed by Mr. Martineau, and my answer to it, have been accessible to all. The question, in my words, is briefly this: 'A man can say, "I feel, I think, I love," but how does consciousness infuse itself into the problem?' And here is my answer: The passage from the physics of the brain to the corresponding facts of consciousness is unthinkable. Granted that a definite thought and a definite molecular action in the brain occur simultaneously; we do not possess the intellectual organ, nor apparently any rudiment of the organ, which would enable us to pass, by a process of reasoning, from the one to the other. They appear together, but we do not know why. Were our minds and senses so expanded, strengthened, and illuminated, as to enable us to see and feel the very molecules of the brain; were we capable of following all their motions, all their groupings, all their electric discharges, if such there be; and were we intimately acquainted with the corresponding states of thought and feeling, we should be as far as ever from the solution of the problem, "How are these physical processes connected with the facts of consciousness?" The chasm between the two classes of phenomena would still remain intellectually impassable.'[1]

Compare this with the answer which Mr. Martineau puts into the mouth of *his* physicist, and with which I am generally credited by Mr. Martineau's readers, both in England and America: '"It [the problem of consciousness] does not daunt me at all. Of course you understand that all along my atoms have been affected by gravitation and polarity; and now I have only to insist with Fechner on a difference among molecules: there are the *inorganic*, which can change only their *place*, like the particles in an undulation; and there are the *organic*, which can change *their order*, as in a globule that turns itself inside out. With an adequate number of these our problem will be manageable." "Likely enough," we may say ["entirely unlikely," say I], "seeing how careful you are to provide for all emergencies; and if any hitch should occur in the next step, where you will have to pass from mere sentiency to thought and will, you can again look in upon your atoms, and fling among them a handful of Leibnitz's monads, to serve as souls in little, and be ready, in a latent form, with that Vorstellungs-fähigkeit which our picturesque interpreters of nature so much prize."'

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[1] Bishop Butler's reply to the Lucretian in the 'Belfast Address' is all in the same strain.

'But surely,' continues Mr. Martineau, 'you must observe that this "matter" of yours alters its style with every change of service: starting as a beggar with scarce a rag of "property" to cover its bones, it turns up as a prince when large undertakings are wanted. "We must radically change our notions of matter," says Professor Tyndall; and then, he ventures to believe, it will answer all demands, carrying "the promise and potency of all terrestrial life." If the measure of the required "change in our notions" had been specified, the proposition would have had a real meaning, and been susceptible of a test. It is easy travelling through the stages of such an hypothesis; you deposit at your bank a round sum ere you start, and, drawing on it piecemeal at every pause, complete your grand tour without a debt.'

The last paragraph of this argument is forcibly and ably stated. On it I am willing to try conclusions with Mr Martineau. I may say, in passing, that I share his contempt for the picturesque interpretation of nature, if accuracy of vision be thereby impaired. But the term Vorstellungs-fähigkeit, as used by me, means the power of definite mental presentation, of attaching to words the corresponding objects of thought, and of seeing these in their proper relations, without the interior haze and soft penumbral borders which the theologian loves. To this mode of 'interpreting nature' I shall to the best of my ability now adhere.

Neither of us, I trust, will be afraid or ashamed to begin at the alphabet of this question. Our first effort must be to understand each other, and this mutual understanding can only be ensured by beginning low down. Physically speaking, however, we need not go below the sea-level. Let us then travel in company to the Caribbean Sea, and halt upon the heated water. What is that sea, and what is the sun that heats it? Answering for myself, I say that they are both *matter*. I fill a glass with the sea-water and expose it on the deck of the vessel; after some time the liquid has all disappeared, and left a solid residue of salt in the glass behind. We have mobility, invisibility—apparent annihilation. In virtue of

> The glad and secret aid
> The sun unto the ocean paid,

the water has taken to itself wings and flown off as vapour. From the whole surface of the Caribbean Sea such vapour is rising: and now we must follow it—not upon our legs, however, nor in a ship, nor even in a balloon, but by the mind's eye—in other words, by that power of Vorstellung which Mr. Martineau knows so well, and which he so justly scorns when it indulges in loose practices.

Compounding, then, the northward motion of the vapour with the earth's axial rotation, we track our fugitive through the higher atmospheric regions, obliquely across the Atlantic Ocean to Western Europe, and on to our familiar Alps. Here another wonderful metamorphosis occurs. Floating on the cold calm air, and in presence of the cold firmament, the vapour condenses, not only to particles of water, but to particles of crystalline water. These coalesce to stars of snow, which fall upon the mountains in forms so exquisite that, when first seen, they never fail to excite rapture. As to beauty, indeed, they put the work of the lapidary to shame, while as to accuracy they render concrete the abstractions of the geometer. Are these crystals 'matter'? Without presuming to dogmatise, I answer for myself in the affirmative.

Still, a *formative power* has obviously here come into play which did not manifest itself in either the liquid or the vapour. The question now is, Was not the power 'potential' in both of them, requiring only the proper conditions of temperature to bring it into action? Again I answer for myself in the affirmative. I am, however, quite willing to discuss with Mr. Martineau the alternative hypothesis, that an imponderable formative soul unites itself with the substance after its escape from the liquid state. If he should espouse this hypothesis, then I should demand of him an immediate exercise of that Vorstellungs-fähigkeit, with which, in my efforts to think clearly, I can never dispense. I should ask, At what moment did the soul come in? Did it enter at once or by degrees; perfect from the first, or growing and perfecting itself contemporaneously with its own handiwork? I should also ask whether it is localised or diffused? Does it move about as a lonely builder, putting the bits of solid water in their places as soon as the proper temperature has set in? or is it distributed through the entire mass of the crystal? If the latter, then the soul has the shape of the crystal; but if the former, then I should enquire after its shape. Has it legs or arms? If not, I would ask it to be made clear to me how a thing without these appliances can act so perfectly the part of a builder? (I insist on definition, and ask unusual questions, if haply I might thereby banish unmeaning words.) What were the condition and residence of the soul before it joined the crystal? What becomes of it when the crystal is dissolved? Why should a particular temperature be needed before it can exercise its vocation? Finally, is the problem before us in any way simplified by the assumption of its existence? I think it probable that, after a full discussion of the question, Mr. Martineau would agree with me in ascribing the building power displayed in the crystal to the bits of water themselves. At all events, I should count upon his sympathy so far as to believe that he would consider any one unmannerly who would denounce me for rejecting this notion of a separate soul, and for holding the snow-crystal to be 'matter.'

But then what an astonishing addition is here made to the powers of matter! Who would have dreamt, without actually seeing its work, that such a power was locked up in a drop of water? All that we needed to make the action of the *liquid* intelligible was the assumption of Mr. Martineau's 'homogeneous extended atomic solids,' smoothly gliding over one another. But had we supposed the water to be nothing more than this, we should have ignorantly defrauded it of an intrinsic architectural power, which the art of man, even when pushed to its utmost degree of refinement, is incompetent to imitate. I would invite Mr. Martineau to consider how inappropriate his figure of a fictitious bank deposit becomes under these circumstances. The 'account current' of matter receives nothing at my hands which could be honestly kept back from it. If, then, 'Democritus and the mathematicians' so defined matter as to exclude the powers here proved to belong to it, they were clearly wrong, and Mr. Martineau, instead of twitting me with my departure from them, ought rather to applaud me for correcting them.[1]

The reader of my small contributions to the literature which deals with the overlapping margins of Science and Theology, will have noticed how frequently I quote Mr. Emerson. I do so mainly because in him we have a poet and a profoundly religious man, who is really and entirely undaunted by the discoveries of Science, past, present, or prospective. In his case Poetry, with the joy of a bacchanal, takes her graver brother Science by the hand, and cheers him with immortal laughter. By Emerson scientific conceptions are continually transmuted into the finer forms and warmer hues of an ideal world. Our present theme is touched upon in the lines—

> The journeying atoms, primordial wholes
> Firmly draw, firmly drive by their animate poles.

As regards veracity and insight these few words out-weigh, in my estimation, all the formal learning expended by Mr. Martineau in those disquisitions on Force, where he treats the physicist as a conjuror, and speaks so wittily of atomic polarity. In fact, without this notion of polarity—this 'drawing' and 'driving'—this attraction and repulsion, we stand as stupidly dumb before the phenomena of Crystallisation as a Bushman before the phenomena of the Solar System. The genesis and growth of the notion I have endeavoured to make clear in my third Lecture on Light, and in the article on 'Matter and Force' published in this volume.

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[1] Definition implies previous examination of the object defined, and is open to correction or modification as knowledge of the object increases. Such increased knowledge has radically changed our conceptions of the luminiferous æther, converting its vibrations from longitudinal into transverse. Such changes also Mr. Martineau's conceptions of matter are doomed to undergo.

Our further course is here foreshadowed. A Sunday or two ago I stood under an oak planted by Sir John Moore, the hero of Corunna. On the ground near the tree little oaklets were successfully fighting for life with the surrounding vegetation. The acorns had dropped into the friendly soil, and this was the result of their interaction. What is the acorn? what the earth? and what the sun, without whose heat and light the tree could not become a tree, however rich the soil, and however healthy the seed? I answer for myself as before—all 'matter.' And the heat and light which here play so potent a part are acknowledged to be motions of matter. By taking something much lower down in the vegetable kingdom than the oak, we might approach much more nearly to the case of crystallisation already discussed; but this is not now necessary.

If, instead of conceding the sufficiency of matter here, Mr. Martineau should fly to the hypothesis of a vegetative soul, all the questions before asked in relation to the snow-star become pertinent. I would invite him to go over them one by one, and consider what replies he will make to them. He may retort by asking me, 'Who infused the principle of life into the tree?' I say, in answer, that our present question is not this, but another—not who made the tree, but what *is* it? Is there anything besides matter in the tree? If so, what, and where? Mr. Martineau may have begun by this time to discern that it is not 'picturesqueness,' but cold precision, that my Vorstellungs-fähigkeit demands. How, I would ask, is this vegetative soul to be presented to the mind? where did it flourish before the tree grew? and what will become of it when the tree is sawn into planks, or consumed in fire?

Possibly Mr. Martineau may consider the assumption of this soul to be as untenable and as useless as I do. But then if the power to build a tree be conceded to pure matter, what an amazing expansion of our notions of the 'potency of matter' is implied in the concession! Think of the acorn, of the earth, and of the solar light and heat—was ever such necromancy dreamt of as the production of that massive trunk, those swaying boughs and whispering leaves, from the interaction of these three factors? In this interaction, moreover, consists what we call *life*. It will be seen that I am not in the least insensible to the wonder of the tree; nay, I should not be surprised if, in the presence of this wonder, I feel more perplexed and overwhelmed than Mr. Martineau himself.

Consider it for a moment. There is an experiment, first made by Wheatstone, where the music of a piano is transferred from its sound-board, through a thin wooden rod, across several silent rooms in succession, and poured out at a distance from the instrument. The strings of the piano vibrate, not singly, but ten at a time. Every string subdivides, yielding not one note, but a dozen. All these vibrations and subvibrations are crowded together into a bit of deal not more than a quarter of a square inch in section. Yet no note is lost. Each vibration asserts its individual rights; and all are, at last, shaken forth into the air by a second sound-board, against which the distant end of the rod presses. Thought ends in amazement when it seeks to realise the motions of that rod as the music flows through it. I turn to my tree and observe its roots, its trunk, its branches, and its leaves. As the rod conveys the music, and yields it up to the distant air, so does the trunk convey the matter and the motion—the shocks and pulses and other vital actions—which eventually emerge in the umbrageous foliage of the tree. I went some time ago through the greenhouse of a friend. He had ferns from Ceylon, the branches of which were in some cases not much thicker than an ordinary pin—hard, smooth, and cylindrical—often leafless for a foot or more. But at the end of every one of them the unsightly twig unlocked the exuberant beauty hidden within it, and broke forth into a mass of fronds, almost large enough to fill the arms. We stand here upon a higher level of the wonderful: we are conscious of a music subtler than that of the piano, passing unheard through these tiny boughs, and issuing in what Mr. Martineau would opulently call the 'clustered magnificence' of the leaves. Does it lessen my amazement to know that every cluster, and every leaf—their form and texture—lie, like the music in the rod, in the molecular structure of these apparently insignificant stems? Not so. Mr. Martineau weeps for 'the beauty of the flower fading into a necessity.' I care not whether it comes to me through necessity or through freedom, my delight in it is all the same. I see what he sees with a wonder superadded. To me, as to him, not even Solomon in all his glory was arrayed like one of these.

I have spoken above as if the assumption of a soul would save Mr. Martineau from the inconsistency of crediting pure matter with the astonishing building power displayed in crystals and trees. This, however, would not be the necessary result; for it would remain to be proved that the soul assumed is not itself matter. When a boy I learnt from Dr. Watts that the souls of conscious brutes are mere matter. And the man who would claim for matter the human soul itself, would find himself in very orthodox company. 'All that is created,' says Fauste, a famous French bishop of the fifth century, 'is matter. The soul occupies a place; it is enclosed in a body; it quits the body at death, and returns to it at the resurrection, as in the case of Lazarus; the distinction between Hell and Heaven, between eternal pleasures and eternal pains, proves that, even after death, souls occupy a place and are corporeal. God only is incorporeal.' Tertullian, moreover, was quite a physicist in the definiteness of his conceptions regarding the soul. 'The materiality of the soul,' he says, 'is evident from the evangelists. A human soul is there expressly pictured as suffering in hell; it is placed in the middle of a flame, its tongue feels a cruel agony, and it implores a drop of water at the hands of a happier soul. *Wanting materiality,*' adds Tertullian, '*all this would be without meaning.*'[1]

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[1] The foregoing extracts, which M. Alglave recently brought to light for the benefit of the Bishop of Orleans, are taken from the sixth Lecture of the 'Cours d'Histoire Moderne' of that most orthodox of statesmen, M. Guizot. 'I could multiply,' continues M. Guizot, 'these citations to infinity, and they prove that in the first centuries of our era the materiality of the soul was an opinion not only permitted, but dominant.' Dr. Moriarty, and the synod which he recently addressed, obviously forget their own antecedents.

I have glanced at inorganic nature—at the sea, and the sun, and the vapour, and the snow-flake, and at organic nature as represented by the fern and the oak. That same sun which warmed the water and liberated the vapour, exerts a subtler power on the nutriment of the tree. It takes hold of matter wholly unfit for the purposes of nutrition, separates its nutritive from its non-nutritive portions, gives the former to the vegetable, and carries the others away. Planted in the earth, bathed by the air, and tended by the sun, the tree is traversed by its sap, the cells are formed, the woody fibre is spun, and the whole is woven to a texture wonderful even to the naked eye, but a million-fold more so to microscopic vision. Does consciousness mix in any way with these processes? No man can tell. Our only ground for a negative conclusion is the absence of those outward manifestations from which feeling is usually inferred. But even these are not entirely absent. In the greenhouses of Kew we may see that a leaf can close, in response to a proper stimulus, as promptly as the human fingers themselves; and while there Dr. Hooker will tell us of the wondrous fly-catching and fly-devouring power of the Dionæa. No man can say that the feelings of the animal are not represented by a drowsier consciousness in the vegetable world. At all events, no line has ever been drawn between the conscious and the unconscious; for the vegetable shades into the animal by such fine gradations, that is impossible to say where the one ends and the other begins.

In all such enquiries we are necessarily limited by our own powers: we observe what our senses, armed

Their boasted succession from the early Church renders them the direct offspring of a 'materialism' more 'brutal' than any ever enunciated by me.

with the aids furnished by Science, enable us to observe; nothing more. The evidences as to consciousness in the vegetable world depend wholly upon our capacity to observe and weigh them. Alter the capacity, and the evidence would alter too. Would that which to us is a total absence of any manifestation of consciousness be the same to a being with our capacities indefinitely multiplied? To such a being I can imagine not only the vegetable, but the mineral world, responsive to the proper irritants, the response differing only in degree from those exaggerated manifestations, which, in virtue of their magnitude, appeal to our weak powers of observation.

Our conclusion, however, must be based, not on powers that we imagine, but upon those that we possess. What do they reveal? As the earth and atmosphere offer themselves as the nutriment of the vegetable world, so does the latter, which contains no constituent not found in inorganic nature, offer itself to the animal world. Mixed with certain inorganic substances—water, for example—the vegetable constitutes, in the long run, the sole sustenance of the animal. Animals may be divided into two classes, the first of which can utilise the vegetable world immediately, having chemical forces strong enough to cope with its most refractory parts; the second class use the vegetable world mediately; that is to say, after its finer portions have been extracted and stored up by the first. But in neither class have we an atom newly created. The animal world is, so to say, a distillation through the vegetable world from inorganic nature.

From this point of view all three worlds would constitute a unity, in which I picture life as immanent everywhere. Nor am I anxious to shut out the idea that the life here spoken of, may be but a subordinate part and function of a Higher Life, as the living moving blood is subordinate to the living man. I resist no such idea as long as it is not dogmatically imposed. Left for the human mind freely to operate upon, the idea has ethical vitality; but, stiffened into a dogma, the inner force disappears, and the outward yoke of a usurping hierarchy takes its place.

The problem before us is, at all events, capable of definite statement. We have on the one hand strong grounds for concluding that the earth was once a molten mass. We now find it not only swathed by an atmosphere, and covered by a sea, but also crowded with living things. The question is, How were they introduced? Certainty may be as unattainable here as Bishop Butler held it to be in matters of religion; but in the contemplation of probabilities the thoughtful mind is forced to take a side. The conclusion of Science, which recognises unbroken causal connection between the past and the present, would undoubtedly be that the molten earth contained within it elements of life, which grouped themselves into their present forms as the planet cooled. The difficulty and reluctance encountered by this conception, arise solely from the fact that the theologic conception obtained a prior footing in the human mind. Did the latter depend upon reasoning alone, it could not hold its ground for an hour against its rival. But it is warmed into life and strength by associated hopes and fears—and not only by these, which are more or less mean, but by that loftiness of thought and feeling which lifts its possessor above the atmosphere of self, and which the theologic idea, in its nobler forms, has engendered in noble minds.

Were not man's origin implicated, we should accept without a murmur the derivation of animal and vegetable life from what we call inorganic nature. The conclusion of pure intellect points this way and no other. But the purity is troubled by our interests in this life, and by our hopes and fears regarding the life to come. Reason is traversed by the emotions, anger rising in the weaker heads to the height of suggesting that the suppression of the enquirer by the arm of the law would be an act agreeable to God, and serviceable to man. But this foolishness is more than neutralised by the sympathy of the wise; and in England at least, so long as the courtesy which befits an earnest theme is adhered to, such sympathy is ever ready for an honest man. None of us here need shrink from saying all that he has a right to say. We ought, however, to remember that it is not only a band of Jesuits, weaving their schemes of intellectual slavery, under the innocent guise 'of education,' that we are opposing. Our foes are to some extent of our own household, including not only the ignorant and the passionate, but a minority of minds of high calibre and culture, lovers of freedom moreover, who, though its objective hull be riddled by logic, still find the ethic life of their religion unimpaired. But while such considerations ought to influence the *form* of our argument, and prevent it from ever slipping out of the region of courtesy into that of scorn or abuse, its *substance*, I think, ought to be maintained and presented in unmitigated strength.

In the year 1855 the chair of philosophy in the University of Munich happened to be filled by a Catholic priest of great critical penetration, great learning, and great courage, who had borne the brunt of battle long before Döllinger. His Jesuit colleagues, he knew, inculcated the belief that every human soul is sent into the world from God by a separate and supernatural act of creation. In a work entitled the 'Origin of the Human Soul,' Professor Frohschammer, the philosopher here alluded to, was hardy enough to question this doctrine, and to affirm that man, body and soul, comes from his parents, the act of creation being, therefore, mediate and secondary only. The Jesuits keep a sharp look out on all temerities of this kind; and their organ, the 'Civilità Cattolica,' immediately pounced upon Frohschammer. His book was branded as 'pestilent,' placed in the Index, and stamped with the condemnation of the Church.[1] The Jesuit notion does not err on the score of indefiniteness. According to it, the Power whom Goethe does not dare to name, and whom Gassendi and Clerk Maxwell present to us under the guise of a 'Manufacturer' of atoms, turns out annually, for England and Wales alone, a quarter of a million of new souls. Taken in connection with the dictum of Mr. Carlyle, that this annual increment to our population are 'mostly fools,' but little profit to the human heart seems derivable from this mode of regarding the Divine operations.

But if the Jesuit notion be rejected, what are we to accept? Physiologists say that every human being comes from an egg not more than the $\frac{1}{120}$th of an inch in diameter. Is this egg matter? I hold it to be so, as much as the seed of a fern or of an oak. Nine months go to the making of it into a man. Are the additions made during this period of gestation drawn from matter? I think so undoubtedly. If there be anything besides matter in the egg, or in the infant subsequently slumbering in the womb, what is it? The questions already asked with reference to the stars of snow may be here repeated. Mr. Martineau will complain that I am disenchanting the babe of its wonder; but is this the case? I figure it growing in the womb, woven by a something not itself, without conscious participation on the part of either father or mother, and appearing in due time a living miracle, with all its organs and all their implications. Consider the work accomplished during these nine months in forming the eye alone—with its lens, and its humours, and its miraculous retina behind. Consider the ear with its tympanum, cochlea, and Corti's organ—an instrument of three thousand strings, built adjacent to the brain, and employed by it to sift, separate, and interpret, antecedent to all consciousness, the sonorous tremors of the external world. All this has been accomplished, not only without man's contrivance, but without his knowledge, the secret of his own organisation having been withheld from him since his birth in the immeasurable past, until these latter days. Matter I define as that mysterious thing by which all this is accomplished. How it came to have this power is a question on which I never ventured an opinion. If, then, Matter starts as 'a beggar,' it is, in my view, because the Jacobs of theology have deprived it of its birthright. Mr. Martineau need fear no disenchantment. Theories of evolution go but a short way towards the explanation of this mystery; the Ages, let us hope, will at length give us a Poet competent to deal with it aright.

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[1] King Maximilian II. brought Liebig to Munich, he helped Helmholtz in his researches, and loved to liberate and foster science. But through his liberal concession of power to the Jesuits in the schools, he did far more damage to the intellectual freedom of his country than his superstitious predecessor Ludwig I. Priding himself on being a German Prince, Ludwig would not tolerate the interference of the Roman party with the political affairs of Bavaria.

There are men, and they include amongst them some of the best of the race of man, upon whose minds this mystery falls without producing either warmth or colour. The 'dry light' of the intellect suffices for them, and they live their noble lives untouched by a desire to give the mystery shape or expression. There are, on the other hand, men whose minds are warmed and coloured by its presence, and who, under its stimulus, attain to moral heights which have never been overtopped. Different spiritual climates are necessary for the healthy existence of these two classes of men; and different climates must be accorded them. The history of humanity, however, proves the experience of the second class to illustrate the most pervading need. The world will have religion of some kind, even though it should fly for it to the intellectual whoredom of 'spiritualism.' What is really wanted is the lifting power of an ideal element in human life. But the free play of this power must be preceded by its release from the practical materialism of the present, as well as from the torn swaddling bands of the past. It is now in danger of being stupefied by the one, or strangled by the other. I look, however, forward to a time when the strength, insight, and elevation which now visit us in mere hints and glimpses, during moments 'of clearness and vigour,' shall be the stable and permanent possession of purer and mightier minds than ours—purer and mightier, partly because of their deeper knowledge of matter and their more faithful conformity to its laws.

XII.

FERMENTATION, AND ITS BEARINGS ON SURGERY AND MEDICINE.[1]

ONE of the most remarkable characteristics of the age in which we live, is its desire and tendency to connect itself organically with preceding ages—to ascertain how the state of things that now is came to be what it is. And the more earnestly and profoundly this problem is studied, the more clearly comes into view the vast and varied debt which the world of to-day owes to that fore-world, in which man by skill, valour, and well-directed strength first replenished and subdued the earth. Our prehistoric fathers may have been savages, but they were clever and observant ones. They founded agriculture by the discovery and development of seeds whose origin is now unknown. They tamed and harnessed their animal antagonists, and sent them down to us as ministers, instead of rivals in the fight for life. Later on, when the claims of luxury added themselves to those of necessity, we find the same spirit of invention at work. We have no historic account of the first brewer, but we glean from history that his art was practised, and its produce relished, more than two thousand years ago. Theophrastus, who was born nearly four hundred years before Christ, described beer as *the wine of barley.* It is extremely difficult to preserve beer in a hot country, still, Egypt was the land in which it was first brewed, the desire of man to quench his thirst with this exhilarating beverage overcoming all the obstacles which a hot climate threw in the way of its manufacture.

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[1] A Discourse delivered before the Glasgow Science Lectures Association, October 19, 1876.

Our remote ancestors had also learned by experience that wine maketh glad the heart of man. Noah, we are informed, planted a vineyard, drank of the wine, and experienced the consequences. But, though wine and beer possess so old a history, a very few years ago no man knew the secret of their formation. Indeed, it might be said that until the present year no thorough and scientific account was ever given of the agencies which come into play in the manufacture of beer, of the conditions necessary to its health, and of the maladies and vicissitudes to which it is subject. Hitherto the art and practice of the brewer have resembled those of the physician, both being founded on empirical observation. By this is meant the observation of facts, apart from the principles which explain them, and which give the mind an intelligent mastery over them. The brewer learnt from long experience the conditions, not the reasons, of success. But he had to contend, and has still to contend, against unexplained perplexities. Over and over again his care has been rendered nugatory; his beer has fallen into acidity or rottenness, and disastrous losses have been sustained, of which he has been unable to assign the cause. It is the hidden enemies against which the physician and the brewer have hitherto contended, that recent researches are dragging into the light of day, thus preparing the way for their final extermination.

Let us glance for a moment at the outward and visible signs of fermentation. A few weeks ago I paid a visit to a private still in a Swiss chalet; and this is what I saw. In the peasant's bedroom was a cask with a very large bunghole carefully closed. The cask contained cherries which had lain in it for fourteen days. It was not entirely filled with the fruit, an air-space being left above the cherries when they were put in. I had the bung removed, and a small lamp dipped into this space. Its flame was instantly extinguished. The oxygen of the air had entirely disappeared, its place being taken by carbonic acid gas.[1] I tasted the cherries: they were very sour, though when put into the cask they were sweet. The cherries and the liquid associated with them were then placed in a copper boiler, to which a copper head was closely fitted. From the head proceeded a copper tube which passed straight through a vessel of cold water, and issued at the other side. Under the open end of the tube was placed a bottle to receive the spirit distilled. The flame of small wood-splinters being applied to the boiler, after a time vapour rose into the head, passed through the tube, was condensed by the cold of the water, and fell in a liquid fillet into the bottle. On being tasted, it proved to be that fiery and intoxicating spirit known in commerce as Kirsch or Kirschwasser.

The cherries, it should be remembered, were left to themselves, no ferment of any kind being added to them. In this respect what has been said of the cherry applies also to the grape. At the vintage the fruit of the vine is placed in proper vessels, and abandoned to its own action. It ferments, producing carbonic acid; its sweetness disappears, and at the end of a certain time the unintoxicating grape-juice is converted into intoxicating wine. Here, as in the case of the cherries, the fermentation is spontaneous—in what sense spontaneous will appear more clearly by-and-by.

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[1] The gas which is exhaled from the lungs after the oxygen of the air has done its duty in purifying the blood, the same also which effervesces from soda water and champagne.

It is needless for me to tell a Glasgow audience that the beer-brewer does not set to work in this way. In the first place the brewer deals not with the juice of fruits, but with the juice of barley. The barley having been steeped for a sufficient time in water, it is drained and subjected to a temperature sufficient to cause the moist grain to germinate; after which, it is completely dried upon a kiln. It then receives the name of *malt*. The malt is crisp to the teeth, and decidedly sweeter to the taste than the original barley. It is ground, mashed up in warm water, then boiled with hops until all the soluble portions have been extracted; the infusion thus produced being called the *wort*. This is drawn off, and cooled as rapidly as possible; then, instead of abandoning the infusion, as the wine-maker does, to its own action, the brewer mixes yeast with his wort, and places it in vessels each with only one aperture open to the air. Soon after the addition of the yeast, a brownish froth, which is really new yeast, issues from the aperture, and falls like a cataract into troughs prepared to receive it. This frothing and foaming of the wort is a proof that the fermentation is active.

Whence comes the yeast which issues so copiously from the fermenting tub? What is this yeast, and how did the brewer become possessed of it? Examine its quantity before and after fermentation. The brewer introduces, say 10 cwts. of yeast; he collects 40, or it may be 50, cwts. The yeast has, therefore, augmented from four to five fold during the fermentation. Shall we conclude that this additional yeast has been spontaneously generated by the wort? Are we not rather reminded of that seed which fell into good ground, and brought forth fruit, some thirty fold, some sixty fold, some an hundred fold? On examination, this notion of organic growth turns out to be more than a mere surmise In the year 1680, when the microscope was still in its infancy, Leeuwenhoek turned the instrument upon this substance, and found it composed of minute globules suspended in a liquid. Thus knowledge rested until 1835, when Cagniard de la Tour in France, and Schwann in Germany, independently, but animated by a common thought, turned microscopes of improved definition and heightened powers upon yeast, and found it budding and sprouting before their eyes. The augmentation of the yeast alluded to above was thus proved to arise from the growth of a minute plant now called *Torula* (or *Saccharomyces*) *Cerevisiæ.* Spontaneous generation is therefore out of the question. The brewer deliberately sows the yeast-plant, which grows and multiplies in the wort as its proper soil. This discovery marks an epoch in the history of fermentation.

But where did the brewer find his yeast? The reply to this question is similar to that which must be given if it were asked where the brewer found his barley. He has received the seeds of both of them from preceding generations. Could we connect without solution of continuity the present with the past, we should probably be able to trace back the yeast employed by my friend Sir Fowell Buxton to-day to that employed by some Egyptian brewer two thousand years ago. But you may urge that there must have been a time when the first yeast-cell was generated. Granted—exactly as there was a time when the first barley-corn was generated. Let not the delusion lay hold of you that a living thing is easily generated because it is small. Both the yeast-plant and the barley-plant lose themselves in the dim twilight of antiquity, and in this our day there is no more proof of the spontaneous generation of the one, than there is of the spontaneous generation of the other.

I stated a moment ago that the fermentation of grape-juice was spontaneous; but I was careful to add, 'in what sense spontaneous will appear more clearly by-and-by.' Now this is the sense meant. The wine-maker does not, like the brewer and distiller, deliberately introduce either yeast, or any equivalent of yeast, into his vats; he does not consciously sow in them any plant, or the germ of any plant; indeed, he has been hitherto in ignorance whether plants or germs of any kind have had anything to do with his operations. Still, when the fermented grape-juice is examined, the living *Torula* concerned in alcoholic fermentation never fails to make its appearance. How is this? If no living germ has been introduced into the wine-vat, whence comes the life so invariably developed there?

You may be disposed to reply, with Turpin and others, that in virtue of its own inherent powers, the grape-juice when brought into contact with the vivifying atmospheric oxygen, runs spontaneously and of its own accord into these low forms of life. I have not the slightest objection to this explanation, provided proper evidence can be adduced in support of it. But the evidence adduced in its favour, as far as I am acquainted with it, snaps asunder under the strain of scientific criticism. It is, as far as I can see, the evidence of men, who however keen and clever as *observers*, are not rigidly trained *experimenters*. These alone are aware of the precautions necessary in investigations of this delicate kind. In reference, then, to the life of the wine-vat, what is the decision of experiment when carried out by competent men? Let a quantity of the clear, filtered 'must' of the grape be so boiled as to destroy such germs as it may have contracted from the air or otherwise. In contact with germless air the uncontaminated must never ferments. All the materials for spontaneous generation are there, but so long as there is no seed sown, there is no life developed, and no sign of that fermentation which is the concomitant of life. Nor need you resort to a boiled liquid. The grape is sealed by its own skin against contamination from without. By an ingenious device Pasteur has extracted from the interior of the grape its pure juice, and proved that in contact with pure air it never acquires the power to ferment itself, nor to produce fermentation in other liquids.[1] It is not, therefore, in the interior of the grape that the origin of the life observed in the vat is to be sought.

What then is its true origin? This is Pasteur's answer, which his well-proved accuracy renders worthy of all confidence. At the time of the vintage microscopic particles are observed adherent, both to the outer surface of the grape and of the twigs which support the grape. Brush these particles into a capsule of pure water. It is rendered turbid by the dust. Examined by a microscope, some of these minute particles are seen to present the appearance of organised cells. Instead of receiving them in water, let them be brushed into the pure inert juice of the grape. Forty-eight hours after this is done, our familiar *Torula* is observed budding and sprouting, the growth of the plant being accompanied by all the other signs of active fermentation. What is the inference to be drawn from this experiment? Obviously that the particles adherent to the external surface of the grape include the germs of that life which, after they have been sown in the juice, appears in such profusion. Wine is sometimes objected to on the ground that fermentation is 'artificial;' but we notice here the responsibility of nature. The ferment of the grape clings like a parasite to the surface of the grape; and the art of the wine-maker from time immemorial has consisted in bringing- and it may be added, ignorantly bringing—two things thus closely associated by nature into actual contact with each other. For thousands of years, what has been done consciously by the brewer, has been done unconsciously by the wine-grower. The one has sown his leaven just as much as the other.

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[1] The liquids of the healthy animal body are also sealed from external contamination. Pure blood, for example, drawn with due precautions from the veins, will never ferment or putrefy in contact with pure air.

Nor is it necessary to impregnate the beer-wort with yeast to provoke fermentation. Abandoned to the contact of our common air, it sooner or later ferments; but the chances are that the produce of that fermentation, instead of being agreeable, would be disgusting to the taste. By a rare accident we might get the true alcoholic fermentation, but the odds against obtaining it would be enormous. Pure air acting upon a lifeless liquid will never provoke fermentation; but our ordinary air is the vehicle of numberless germs which act as ferments when they fall into appropriate infusions. Some of them produce acidity, some putrefaction. The germs of our yeast-plant are also in the air; but so sparingly distributed that an infusion like beer-wort, exposed to the air, is almost sure to be taken possession of by foreign organisms. In fact, the maladies of beer are wholly due to the admixture of these objectionable ferments, whose forms and modes of nutrition differ materially from those of the true leaven.

Working in an atmosphere charged with the germs of these organisms, you can understand how easy it is to fall into error in studying the action of any one of them. Indeed it is only the most accomplished experimenter, who, moreover, avails himself of every means of checking his conclusions, that can walk without tripping through this land of pitfalls. Such a man the French chemist Pasteur has hitherto proved himself to be. He has taught us how to separate the commingled ferments of our air, and to study their pure individual action. Guided by him, let us fix our attention more particularly upon the growth and action of the true yeast-plant under different conditions. Let it be sown in a fermentable liquid, which is supplied with plenty of pure air. The plant will flourish in the aërated infusion, and produce large quantities of carbonic acid gas—a compound, as you know, of carbon and oxygen. The oxygen thus consumed by the plant is the free oxygen of the air, which we suppose to be abundantly supplied to the liquid. The action is so far similar to the respiration of animals, which inspire oxygen and expire carbonic acid. If we examine the liquid even when the vigour of the plant has reached its maximum, we hardly find in it a trace of alcohol. The yeast has grown and flourished, but it has almost ceased to act as a ferment. And could every individual yeast-cell seize, without any impediment, free oxygen from the surrounding liquid, it is certain that it would cease to act as a ferment altogether.

What, then, are the conditions under which the yeast-plant must be placed so that it may display its characteristic quality? Reflection on the facts already referred to suggests a reply, and rigid experiment confirms the suggestion. Consider the Alpine cherries in their closed vessel. Consider the beer in its barrel, with a single small aperture open to the air, through which it is observed not to imbibe oxygen, but to pour forth carbonic acid. Whence come the volumes of oxygen necessary to the production of this latter gas? The small quantity of atmospheric air dissolved in the wort and overlying it would be totally incompetent to supply the necessary oxygen. In no other way can the yeast-plant obtain the gas necessary for its respiration than by wrenching it from surrounding substances in which the oxygen exists, not free, but in a state of combination. It decomposes the sugar of the solution in which it grows, produces heat, breathes forth carbonic acid gas, and one of the liquid products of the decomposition is our familiar alcohol. The act of fermentation, then, is a result of the effort of the little plant to maintain its respiration by means of *combined* oxygen, when its supply of free oxygen is cut off. As defined by Pasteur, fermentation is *life without air.*

But here the knowledge of that thorough investigator comes to our aid to warn us against errors which have been committed over and over again. It is not all yeast-cells that can thus live without air and provoke fermentation. They must be young cells which have caught their vegetative vigour from contact with free oxygen. But once possessed of this vigour the yeast may be transplanted into a saccharine infusion absolutely purged of air, where it will continue to live at the expense of the oxygen, carbon, and other constituents of the infusion. Under these new conditions its life, *as a plant*, will be by no means so vigorous as when it had a supply of free oxygen, but its action *as a ferment* will be indefinitely greater.

Does the yeast-plant stand alone in its power of provoking alcoholic fermentation? It would be singular if amid the multitude of low vegetable forms no other could be found capable of acting in a similar way. And here again we have occasion to marvel at that sagacity of observation among the ancients to which we owe so vast a debt. Not only did they discover the alcoholic ferment of yeast, but they had to exercise a wise selection in picking it out from others, and giving it special prominence. Place an old boot in a moist place, or expose common paste or a pot of jam to the air; it soon becomes coated with a blue-green mould, which is nothing else than the fructification of a little plant called *Penicillium glaucum.* Do not imagine that the mould has sprung spontaneously from boot, or paste, or jam; its germs, which are abundant in the air, have been sown, and have germinated, in as legal and legitimate a way as thistle-seeds wafted by the wind to a proper soil. Let the minute spores of *Penicillium* be sown in a fermentable liquid, which has been previously so boiled as to kill all other spores or seeds which it may contain; let pure air have free access to the mixture; the *Penicillium* will grow rapidly, striking long filaments into the liquid, and fructifying at its surface. Test the infusion at various stages of the plant's growth, you will never find in it a trace of alcohol. But forcibly submerge the little plant, push it down deep into the liquid, where the quantity of free oxygen that can reach it is insufficient for its needs, it immediately begins to act as a ferment, supplying itself with oxygen by the decomposition of the sugar, and producing alcohol as one of the results of the decomposition. Many other low microscopic plants act in a similar manner. In aërated liquids they flourish without any production of alcohol, but cut off from free oxygen they act as ferments, producing alcohol exactly as the real alcoholic leaven produces it, only less copiously. For the right apprehension of all these facts we are indebted to Pasteur.

In the cases hitherto considered, the fermentation is proved to be the invariable correlative of *life*, being produced by organisms foreign to the fermentable substance. But the substance itself may also have within it, to some extent, the motive power of fermentation. The yeast-plant, as we have learned, is an assemblage of living cells; but so at bottom, as shown by Schleiden and Schwann, are all living organisms. Cherries, apples, peaches, pears, plums, and grapes, for example, are composed of cells, each of which is a living unit. And here I have to direct your attention to a point of extreme interest. In 1821, the celebrated French chemist, Bérard, established the important fact that all ripening fruit, exposed to the free atmosphere, absorbed the oxygen of the atmosphere and liberated an approximately equal volume of carbonic acid. He also found that when ripe fruits were placed in a confined atmosphere, the oxygen of the atmosphere was first absorbed, and an equal volume of carbonic acid given out. But the process did not end here. After the oxygen had vanished, carbonic acid, in considerable quantities, continued to be exhaled by the fruits, which at the same time lost a portion of their sugar, becoming more acid to the taste, though the absolute quantity of acid was not augmented. This was an observation of capital importance, and Bérard had the sagacity to remark that the process might be regarded as a kind of fermentation.

Thus the living cells of fruits can absorb oxygen and breathe out carbonic acid, exactly like the living cells of the leaven of beer. Supposing the access of oxygen suddenly cut off, will the living fruit-cells as suddenly die, or will they continue to live as yeast lives, by extracting oxygen from the saccharine juices round them? This is a question of extreme theoretic significance. It was first answered affirmatively by the able and conclusive experiments of Lechartier and Bellamy, and the answer was subsequently confirmed and explained by the experiments and the reasoning of Pasteur. Bérard only showed the absorption of oxygen and the production of carbonic acid; Lechartier and Bellamy proved the production of alcohol, thus completing the evidence that it was a case of real fermentation, though the common alcoholic ferment was absent. So full was Pasteur of the idea that the cells of a fruit would continue to live at the expense of the sugar of the fruit, that once in his laboratory, while conversing on these subjects with M. Dumas, he exclaimed, 'I will wager that if a grape be plunged into an atmosphere of carbonic acid, it will produce alcohol and carbonic acid by the continued life of its own cells—that they will act for a time like the cells of the true alcoholic leaven.' He made the experiment, and found the result to be what he had foreseen. He then extended the enquiry. Placing under a bell-jar twenty-four plums, he filled the jar with carbonic acid gas; beside it he placed twenty-four similar plums uncovered. At the end of eight days, he removed the plums from the jar, and compared them with the others. The difference was extraordinary. The uncovered fruits had become soft, watery, and very sweet; the others were firm and hard, their fleshy portions being not at all watery. They had, moreover, lost a considerable quantity of their sugar. They were afterwards bruised, and the juice was distilled. It yielded six and a half grammes of alcohol, or one per cent. of the total weight of the plums. Neither in these plums, nor in the grapes first experimented on by Pasteur, could any trace of the ordinary alcoholic leaven be found. As previously proved by Lechartier and Bellamy, the fermentation was the work of the living cells of the fruit itself, after air had been denied to them. When, moreover, the cells were destroyed by bruising, no fermentation ensued. The fermentation was the correlative of a vital act, and it ceased when life was extinguished.

Lüdersdorf was the first to show by this method that yeast acted, not, as Liebig had assumed, in virtue of its *organic*, but in virtue of its *organised* character. He destroyed the cells of yeast by rubbing them on a ground glass plate, and found that with the destruction of the organism, though its chemical constituents remained, the power to act as a ferment totally disappeared.

One word more in reference to Liebig may find a place here. To the philosophic chemist thoughtfully pondering these phenomena, familiar with the conception of molecular motion, and the changes produced by the interactions of purely chemical forces, nothing could be more natural than to see in the process of fermentation a simple illustration of molecular instability, the ferment propagating to surrounding molecular groups the overthrow of its own tottering combinations. Broadly considered, indeed, there is a certain amount of truth in this theory; but Liebig, who propounded it, missed the very kernel of the phenomena when he overlooked or contemned the part played in fermentation by microscopic life. He looked at the matter too little with the eye of the body, and too much with the spiritual eye. He practically neglected the microscope, and was unmoved by the knowledge which its revelations would have poured in upon his mind. His hypothesis, as I have said, was natural—nay it was a striking illustration of Liebig's power to penetrate and unveil molecular actions; but it was an error, and as such has proved an *ignis fatuus* instead of a *pharos* to some of his followers.

I have said that our air is full of the germs of ferments differing from the alcoholic leaven, and sometimes seriously interfering with the latter. They are the weeds of this microscopic garden which often overshadow and choke the flowers. Let us take an illustrative case. Expose milk to the air. It will, after a time, turn sour, separating like blood into clot and serum. Place a drop of this sour milk under a powerful microscope and watch it closely. You see the minute butter-globules animated by that curious quivering motion called the Brownian motion. But let not this attract your attention too much, for it is another motion that we have now to seek. Here and there you observe a greater disturbance than ordinary among the globules; keep your eye upon the place of tumult, and you will probably see emerging from it a long eel-like organism, tossing the globules aside and wriggling more or less rapidly across the field of the microscope. Familiar with one sample of this organism, which from its motions receives the name of *vibrio*, you soon detect numbers of them. It is these organisms, and other analogous though apparently motionless ones, which by decomposing the milk render it sour and putrid. They are the lactic and putrid ferments, as the yeast-plant is the alcoholic ferment of sugar. Keep them and their germs out of your milk and it will continue sweet. But milk may become putrid without becoming sour. Examine such putrid milk microscopically, and you find it swarming with shorter organisms, sometimes associated with the vibrios, sometimes alone, and often manifesting a wonderful alacrity of motion. Keep these organisms and their germs out of your milk and it will never putrefy. Expose a mutton-chop to the air and keep it moist; in summer weather it soon stinks. Place a drop of the juice of the fetid chop under a powerful microscope; it is seen swarming with organisms resembling those in the putrid milk. These organisms, which receive the common name of *bacteria*,[1] are the agents of all putrefaction. Keep them and their germs from your meat and it will remain for ever sweet. Thus we begin to see that within the world of life to which we ourselves belong, there is another living world requiring the microscope for its discernment, but which, nevertheless, has the most important bearing on the welfare of the higher life-world.

And now let us reason together as regards the origin of these bacteria. A granular powder is placed in your hands, and you are asked to state what it is. You examine it, and have, or have not, reason to suspect that seeds of some kind are mixed up in it. To determine this point you prepare a bed in your garden, sow in it the powder, and soon after find a mixed crop of docks and thistles sprouting from your bed. Until this powder was sown neither docks nor thistles ever made their appearance in your garden. You repeat the experiment once, twice, ten times, fifty times. From fifty different beds after the sowing of the powder, you obtain the same crop. What will be your response to the question proposed to you? 'I am not in a condition,' you would say, 'to affirm that every grain of the powder is a dock-seed, or a thistle-seed; but I am in a condition to affirm that both dock and thistle-seeds form, at all events, part of the powder.' Supposing a succession of such powders to be placed in your hands with grains becoming gradually smaller, until they dwindle to the size of impalpable dust particles; assuming that you treat them all in the same way, and that from every one of them in a few days you obtain a definite crop—it may be clover, it may be mustard, it may be mignonette, it may be a plant more minute than any of these, the smallness of the particles, or of the plants that spring from them, does not affect the validity of the conclusion. Without a shadow of misgiving you would conclude that the powder must have contained the seeds or germs of the life observed. There is not in the range of physical science, an experiment more conclusive nor an inference safer than this one.

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[1] Doubtless organisms exhibiting grave specific differences are grouped together under this common name.

Supposing the powder to be light enough to float in the air, and that you are enabled to see it there just as plainly as you saw the heavier powder in the palm of your hand. If the dust sown by the air instead of by the hand produce a definite living crop, with the same logical rigour you would conclude that the germs of this crop must be mixed with the dust. To take an illustration: the spores of the little plant *Penicillium glaucum*, to which I have already referred, are light enough to float in the air. A cut apple, a pear, a tomato, a slice of vegetable marrow, or, as already mentioned, an old moist boot, a dish of paste, or a pot of jam, constitutes a proper soil for the *Penicillium*. Now, if it could be proved that the dust of the air when sown in this soil produces this plant, while, wanting the dust, neither the air, nor the soil, nor both together can produce it, it would be obviously just as certain in this case that the floating dust contains the germs of *Penicillium* as that the powders sown in your garden contained the germs of the plants which sprung from them.

But how is the floating dust to be rendered visible? In this way. Build a little chamber and provide it with a door, windows, and window-shutters. Let an aperture be made in one of the shutters through which a sunbeam can pass. Close the door and windows so that no light shall enter save through the hole in the shutter. The track of the sunbeam is at first perfectly plain and vivid in the air of the room. If all disturbance of the air of the chamber be avoided, the luminous track will become fainter and fainter, until at last it disappears absolutely, and no trace of the beam is to be seen. What rendered the beam visible at first? The floating dust of the air, which, thus illuminated and observed, is as palpable to sense as dust or powder placed on the palm of the hand. In the still air the dust gradually sinks to the floor or sticks to the walls and ceiling, until finally, by this self-cleansing process, the air is entirely freed from mechanically suspended matter.

Thus, far, I think, we have made our footing sure. Let us proceed. Chop up a beefsteak and allow it to remain for two or three hours just covered with warm water; you thus extract the juice of the beef in a concentrated form. By properly boiling the liquid and filtering it, you can obtain from it a perfectly transparent beef-tea. Expose a number of vessels containing this tea to the moteless air of your chamber; and expose a number of vessels containing precisely the same liquid to the dust-laden air. In three days every one of the latter stinks, and examined with the microscope every one of them is found swarming with the bacteria of putrefaction. After three months, or three years, the beef-tea within the chamber is found in every case as sweet and clear, and as free from bacteria, as it was at the moment when it was first put in. There is absolutely no difference between the air within and that without save that the one is dustless and the other dust-laden

Clinch the experiment thus: Open the door of your chamber and allow the dust to enter it. In three days afterwards you have every vessel within the chamber swarming with bacteria, and in a state of active putrefaction. Here, also, the inference is quite as certain as in the case of the powder sown in your garden. Multiply your proofs by building fifty chambers instead of one, and by employing every imaginable infusion of wild animals and tame; of flesh, fish, fowl, and viscera; of vegetables of the most various kinds. If in all these cases you find the dust infallibly producing its crop of bacteria, while neither the dustless air nor the nutritive infusion, nor both together, are ever able to produce this crop, your conclusion is simply irresistible that the dust of the air contains the germs of the crop which has appeared in your infusions. I repeat there is no inference of experimental science more certain than this one. In the presence of such facts, to use the words of a paper lately published in the 'Philosophical Transactions,' it would be simply monstrous to affirm that these swarming crops of bacteria are spontaneously generated.

Is there then no experimental proof of spontaneous generation? I answer without hesitation, *none!* But to doubt the experimental proof of a fact, and to deny its possibility, are two different things, though some writers confuse matters by making them synonymous. In fact, this doctrine of spontaneous generation, in one form or another, falls in with the theoretic beliefs of some of the foremost workers of this age; but it is exactly these men who have the penetration to see, and the honesty to expose, the weakness of the evidence adduced in its support.

And here observe how these discoveries tally with the common practices of life. Heat kills the bacteria, colds numbs them. When my housekeeper has pheasants in charge which she wishes to keep sweet, but which threaten to give way, she partially cooks the birds, kills the infant bacteria, and thus postpones the evil day. By boiling her milk she also extends its period of sweetness. Some weeks ago in the Alps I made a few experiments on the influence of cold upon ants. Though the sun was strong, patches of snow still maintained themselves on the mountain slopes. The ants were found in the warm grass and on the warm rocks adjacent. Transferred to the snow the rapidity of their paralysis was surprising. In a few seconds a vigorous ant, after a few languid struggles, would wholly lose its power of locomotion and lie practically dead upon the snow. Transferred to the warm rock, it would revive, to be again smitten with death-like numbness when retransferred to the snow. What is true of the ant is specially true of our bacteria. Their active life is suspended by cold, and with it their power of producing or continuing putrefaction. This is the whole philosophy of the preservation of meat by cold. The fishmonger, for example, when he surrounds his very assailable wares by lumps of ice, stays the process of putrefaction by reducing to numbness and inaction the organisms which produce it, and in the absence of which his fish would remain sweet and sound. It is the astonishing activity into which these bacteria are pushed by warmth that renders a single summer's day sometimes so disastrous to the great butchers of London and Glasgow. The bodies of guides lost in the crevasses of Alpine glaciers have come to the surface forty years after their interment, without the flesh showing any sign of putrefaction. But the most astonishing case of this kind is that of the hairy elephant of Siberia which was found incased in ice. It had been buried for ages, but when laid bare its flesh was sweet, and for some time afforded copious nutriment to the wild beasts which fed upon it.

Beer is assailable by all the organisms here referred to, some of which produce acetic, some lactic, and some butyric acid, while yeast is open to attack from the bacteria of putrefaction. In relation to the particular beverage the brewer wishes to produce, these foreign ferments have been properly called *ferments of disease.* The cells of the true leaven are globules, usually somewhat elongated. The other organisms are more or less rod-like or eel-like in shape, some of them being beaded so as to resemble necklaces. Each of these organisms produces a fermentation and a flavour peculiar to itself. Keep them out of your beer and it remains for ever unaltered. Never without them will your beer contract disease. But their germs are in the air, in the vessels employed in the brewery; even in the yeast used to impregnate the wort. Consciously or unconsciously, the art of the brewer is directed against them. His aim is to paralyze, if he cannot annihilate them.

For beer, moreover, the question of temperature is one of supreme importance; indeed, the recognised influence of temperature is causing on the continent of Europe a complete revolution in the manufacture of beer. When I was a student in Berlin, in 1851, there were certain places specially devoted to the sale of Bavarian beer, which was then making its way into public favour. This beer is prepared by what is called the process of *low fermentation;* the name being given partly because the yeast of the beer, instead of rising to the top and issuing through the bunghole, falls to the bottom of the cask; but partly, also, because it is produced at a low temperature. The other and older process, called *high fermentation*, is far more handy, expeditious, and cheap. In high fermentation eight days suffice for the production of the beer; in low fermentation, ten, fifteen, even twenty days are found necessary. Vast quantities of ice, moreover, are consumed in the process of low fermentation. In the single brewery of Dreher, of Vienna, a hundred million pounds of ice are consumed annually in cooling the wort and beer. Notwithstanding these obvious and weighty drawbacks, the low fermentation is rapidly displacing the high upon the Continent. Here are some statistics which show the number of breweries of both kinds existing in Bohemia in 1863, 1865, and 1870:—

	1860.	1865.	1870.
High Fermentation . .	281	81	18
Low Fermentation . .	135	459	831

Thus in ten years the number of high-fermentation breweries fell from 281 to 18, while the number of low-fermentation breweries rose from 135 to 831. The sole reason for this vast change—a change which involves a great expenditure of time, labour, and money—is the additional command which it gives the brewer over the fortuitous ferments of disease. These ferments, which, it is to be remembered, are living organisms, have their activity suspended by temperatures below 10° C., and as long as they are reduced to torpor the beer remains untainted either by acidity or putrefaction. The beer of low fermentation is brewed in winter, and kept in cool cellars; the brewer being thus enabled to dispose of it at his leisure, instead of forcing its consumption to avoid the loss involved in its alteration if kept too long. Hops, it may be remarked, act to some extent as an antiseptic to beer. The essential oil of the hop is bactericidal: hence the strong impregnation with hop juice of all beer intended for exportation.

These low organisms, which one might be disposed to regard as the beginnings of life, were we not warned that the microscope, precious and perfect as it is, has no power to show us the real beginnings of life, are by no means purely useless or purely mischievous in the economy of nature. They are only noxious when out of their proper place. They exercise a useful and valuable function as the burners and consumers of dead matter, animal and vegetable, reducing such matter, with a rapidity otherwise unattainable, to innocent carbonic acid and water. Furthermore, they are not all alike, and it is only restricted classes of them that are really dangerous to man. One difference in their habits is worthy of special reference here. Air, or rather the oxygen of the air, which is absolutely necessary to the support of the bacteria of putrefaction, is, according to Pasteur, absolutely deadly to the vibrios which provoke the butyric acid fermentation. This has been illustrated by the following beautiful observation.

A drop of the liquid containing those small organisms is placed upon glass, and on the drop is placed a circle of exceedingly thin glass; for, to magnify them sufficiently, it is necessary that the object-glass of the microscope should come very close to the organisms. Round the edge of the circular plate of glass the liquid is in contact with the air, and incessantly absorbs it, including the oxygen. Here, if the drop be charged with bacteria, we have a zone of very lively ones. But through this living zone, greedy of oxygen and appropriating it, the vivifying gas cannot penetrate to the centre of the film. In the middle, therefore, the bacteria die, while their peripheral colleagues continue active. If a bubble of air chance to be enclosed in the film, round it the bacteria will pirouette and wabble until its oxygen has been absorbed, after which all their motions cease. Precisely the reverse of all this occurs with the vibrios of butyric acid. In their case it is the peripheral organisms that are first killed, the central ones remaining vigorous while ringed by a zone of dead. Pasteur, moreover, filled two vessels with a liquid containing these vibrios; through one vessel he led air, and killed its vibrios in half an hour; through the other he led carbonic acid, and after three hours found the vibrios fully active. It was while observing these differences of deportment fifteen years ago that the thought of life without air, and its bearing upon the theory of fermentation, flashed upon the mind of this admirable investigator.

We now approach an aspect of this question which concerns us still more closely, and will be best illustrated by an actual fact. A few years ago I was bathing in an Alpine stream, and returning to my clothes from the cascade which had been my shower-bath, I slipped upon a block of granite, the sharp crystals of which stamped themselves into my naked shin. The wound was an awkward one, but being in vigorous health at the time, I hoped for a speedy recovery. Dipping a clean pocket-handkerchief into the stream, I wrapped it round the wound, limped home, and remained for four or five days quietly in bed. There was no pain, and at the end of this time I thought myself quite fit to quit my room. The wound, when uncovered, was found perfectly clean, uninflamed, and entirely free from matter. Placing over it a bit of goldbeater's-skin, I walked about all day. Towards evening itching and heat were felt; a large accumulation of matter followed, and I was forced to go to bed again. The waterbandage was restored, but it was powerless to check the action now set up; arnica was applied, but it made matters worse. The inflammation increased alarmingly, until finally I had to be carried on men's shoulders down the mountain and transported to Geneva, where, thanks to the kindness of friends, I was immediately placed in the best medical hands. On the morning after my arrival in Geneva, Dr. Gautier discovered an abscess in my instep, at a distance of five inches from the wound. The two were connected by a channel, or *sinus*, as it is technically called, through which he was able to empty the abscess, without the application of the lance.

By what agency was that channel formed—what was it that thus tore asunder the sound tissue of my instep, and kept me for six weeks a prisoner in bed? In the very room where the water dressing had been removed from my wound and the goldbeater's-skin applied to it, I opened this year a number of tubes, containing perfectly clear and sweet infusions of fish, flesh, and vegetable. These hermetically sealed infusions had been exposed for weeks, both to the sun of the Alps and to the warmth of a kitchen, without showing the slightest turbidity or sign of life. But two days after they were opened the greater number of them swarmed with the bacteria of putrefaction, the germs of which had been contracted from the dust-laden air of the room. And had the matter from my abscess been examined, my memory of its appearance leads me to infer that it would have been found equally swarming with these bacteria—that it was their germs which got into my incautiously opened wound, and that they were the subtile workers that burrowed down my shin, dug the abscess in my instep, and produced effects which might easily have proved fatal.

This apparent digression brings us face to face with the labours of a man who combines the penetration of the true theorist with the skill and conscientiousness of the true experimenter, and whose practice is one continued demonstration of the theory that the putrefaction of wounds is to be averted by the destruction of the germs of bacteria. Not only from his own reports of his cases, but from the reports of eminent men who have visited his hospital, and from the opinions expressed to me by continental surgeons, do I gather that one of the greatest steps ever made in the art of surgery was the introduction of the antiseptic system of treatment, introduced by Professor Lister.

The interest of this subject does not slacken as we proceed. We began with the cherry-cask and beer-vat; we end with the body of man. There are persons born with the power of interpreting natural facts, as there are others smitten with everlasting incompetence in regard to such interpretation. To the former class in an eminent degree belonged the illustrious philosopher Robert Boyle, whose words in relation to this subject have in them the forecast of prophecy. 'And let me add,' writes Boyle in his 'Essay on the Pathological Part of Physik,' 'that he that thoroughly understands the nature of ferments and fermentations shall probably be much better able than he that ignores them, to give a fair account of divers phenomena of several diseases (as well fevers as others), which will perhaps be never properly understood without an insight into the doctrine of fermentations.'

Two hundred years have passed since these pregnant words were written, and it is only in this our day that men are beginning to fully realise their truth. In the domain of surgery the justice of Boyle's surmise has been most strictly demonstrated. But we now pass the bounds of surgery proper, and enter the domain of epidemic disease, including those fevers so sagaciously referred to by Boyle. The most striking analogy between a *contagium* and a ferment is to be found in the power of indefinite self-multiplication possessed and exercised by both. You know the exquisitely truthful figures regarding leaven employed in the New Testament. A particle hid in three measures of meal leavens it all. A little leaven leaveneth the whole lump. In a similar manner, a particle of *contagium* spreads through the human body and may be so multiplied as to strike down whole populations. Consider the effect produced upon the system by a microscopic quantity of the virus of smallpox. That virus is, to all intents and purposes, a seed. It is sown as yeast is sown, it grows and multiplies as yeast grows and multiplies, and it always reproduces itself. To Pasteur we are indebted for a series of masterly researches, wherein he exposes the looseness and general baselessness of prevalent notions regarding the transmutation of one ferment into another. He guards himself against saying it is impossible. The true investigator is sparing in the use of this word, though the use of it is unsparingly ascribed to him; but, as a matter of fact, Pasteur has never been able to effect the alleged transmutation, while he has been always able to point out the open doorways through which the affirmers of such transmutations had allowed error to march in upon them.[1]

The great source of error here has been already alluded to in this discourse. The observers worked in an atmosphere charged with the germs of different organisms; the mere accident of first possession rendering now one organism, now another, triumphant. In different stages, moreover, of its fermentative or putrefactive changes, the same infusion may so alter as to be successively taken possession of by different organisms. Such cases have been adduced to show that the earlier organisms must have been transformed into the later ones, whereas they are simply cases in which different germs, because of changes in the infusion, render themselves valid at different times.

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[1] Those who wish for an illustration of the care necessary in these researches, and of the carelessness with which they have in some cases been conducted, will do well to consult the Rev. W. H. Dallinger's excellent 'Notes on Heterogenesis' in the Octobe**r** number of the *Popular Science Review.*

By teaching us how to cultivate each ferment in its purity—in other words, by teaching us how to rear the individual organism apart from all others,—Pasteur has enabled us to avoid all these errors. And where this isolation of a particular organism has been duly effected it grows and multiplies indefinitely, but no change of it into another organism is ever observed. In Pasteur's researches the Bacterium remained a Bacterium, the Vibrio a Vibrio, the Penicillium a Penicillium, and the Torula a Torula. Sow any of these in a state of purity in an appropriate liquid; you get it, and it alone, in the subsequent crop. In like manner, sow small-pox in the human body, your crop is small-pox. Sow there scarlatina, and your crop is scarlatina. Sow typhoid virus, your crop is typhoid—cholera, your crop is cholera. The disease bears as constant a relation to its contagium as the microscopic organisms just enumerated do to their germs, or indeed as a thistle does to its seed. No wonder then, with analogies so obvious and so striking, that the conviction is spreading and growing daily in strength, that reproductive parasitic life is at the root of epidemic disease—that living ferments finding lodgment in the body increase there and multiply, directly ruining the tissue on which they subsist, or destroying life indirectly by the generation of poisonous compounds within the body. This conclusion, which comes to us with a presumption almost amounting to demonstration, is clinched by the fact that virulently infective diseases have been discovered with which living organisms are as closely and as indissolubly associated as the growth of Torula is with the fermentation of beer.

And here, if you will permit me, I would utter a word of warning to well-meaning people. We have now reached a phase of this question when it is of the very last importance that light should once for all be thrown upon the manner in which contagious and infectious diseases take root and spread. To this end the action of various ferments upon the organs and tissues of the living body must be studied; the habitat of each special organism concerned in the production of each specific disease must be determined, and the mode by which its germs are spread abroad as sources of further infection. It is only by such rigidly accurate enquiries that we can obtain final and complete mastery over these destroyers. Hence, while abhorring cruelty of all kinds, while shrinking sympathetically from all animal suffering—suffering which my own pursuits never call upon me to inflict,—an unbiassed survey of the field of research now opening out before the physiologist causes me to conclude, that no greater calamity could befall the human race than the stoppage of experimental enquiry in this direction. A lady whose philanthropy has rendered her illustrious said to me some time ago, that science was becoming immoral; that the researches of the past, unlike those of the present, were carried on without cruelty. I replied to her that the science of Kepler and Newton, to which she referred, dealt with the laws and phenomena of inorganic nature; but that one great advance made by modern science was in the direction of biology, or the science of life; and that in this new direction scientific enquiry, though at the outset pursued at the cost of some temporary suffering, would in the end prove a thousand times more beneficent than it had ever hitherto been. I said this because I saw that the very researches which the lady deprecated were leading us to such a knowledge of epidemic diseases as will enable us finally to sweep these scourges of the human race from the face of the earth.

This is a point of such capital importance that I should like to bring it home to your intelligence by a single trustworthy illustration. In 1850, two distinguished French observers, MM. Davainne and Rayer, noticed in the blood of animals which had died of the virulent disease called *splenic fever*, small microscopic organisms resembling transparent rods, but neither of them at that time attached any significance to the observation. In 1861, Pasteur published a memoir on the fermentation of butyric acid, wherein he described the organism which provoked it; and after reading this memoir it occurred to Davainne that splenic fever might be a case of fermentation set up within the animal body, by the organisms which had been observed by him and Rayer. This idea has been placed beyond all doubt by subsequent research.

Observations of the highest importance have also been made on splenic fever by Pollender and Brauell. Two years ago, Dr. Burdon Sanderson gave us a very clear account of what was known up to that time of this disorder. With regard to the permanence of the contagium, it had been proved to hang for years about localities where it had once prevailed; and this seemed to show that the rod-like organisms could not constitute the contagium, because their infective power was found to vanish in a few weeks. But other facts established an intimate connection between the organisms and the disease, so that a review of all the facts caused Dr. Sanderson to conclude that the contagium existed in two distinct forms: the one 'fugitive' and visible as transparent rods; the other permanent but 'latent,' and not yet brought within the grasp of the microscope.

At the time that Dr. Sanderson was writing this report, a young German physician, named Koch,[1] occupied with the duties of his profession in an obscure country district, was already at work, applying, during his spare time, various original and ingenious devices to the investigation of splenic fever. He studied the habits of the rod-like organisms, and found the aqueous humour of an ox's eye to be particularly suitable for their nutrition. With a drop of the aqueous humour he mixed the tiniest speck of a liquid containing the rods, placed the drop under his microscope, warmed it suitably, and observed the subsequent action. During the first two hours hardly any change was noticeable; but at the end of this time the rods began to lengthen, and the action was so rapid that at the end of three or four hours they attained from ten to twenty times their original length. At the end of a few additional hours they had formed filaments in many cases a hundred times the length of the original rods. The same filament, in fact, was frequently observed to stretch through several fields of the microscope. Sometimes they lay in straight lines parallel to each other, in other cases they were bent, twisted, and coiled into the most graceful figures; while sometimes they formed knots of such bewildering complexity that it was impossible for the eye to trace the individual filaments through the confusion.

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[1] This, I believe, was the first reference to the researches of Koch made in this country. 1879.

Had the observation ended here an interesting scientific fact would have been added to our previous store, but the addition would have been of little practical value. Koch, however, continued to watch the filaments, and after a time noticed little dots appearing within them. These dots became more and more distinct, until finally the whole length of the organism was studded with minute ovoid bodies, which lay within the outer integument like peas within their shell. By-and-by the integument fell to pieces, the place of the organisms being taken by a long row of seeds or spores. These observations, which were confirmed in all respects by the celebrated naturalist, Cohn of Breslau, are of the highest importance. They clear up the existing perplexity regarding the latent and visible contagia of splenic fever; for in the most conclusive manner, Koch proved the spores, as distinguished from the rods, to constitute the contagium of the fever in its most deadly and persistent form.

How did he reach this important result? Mark the answer. There was but one way open to him to test the activity of the contagium, and that was the inoculation with it of living animals. He operated upon guinea-pigs and rabbits, but the vast majority of his experiments were made upon mice. Inoculating them with the fresh blood of an animal suffering from splenic fever, they invariably died of the same disease within twenty or thirty hours after inoculation. He then sought to determine how the contagium maintained its vitality. Drying the infectious blood containing the rod-like organisms, in which, however, the spores were not developed, he found the contagium to be that which

Dr. Sanderson calls 'fugitive.' It maintained its power of infection for five weeks at the furthest. He then dried blood containing the fully-developed spores, and exposed the substance to a variety of conditions. He permitted the dried blood to assume the form of dust; wetted this dust, allowed it to dry again, permitted it to remain for an indefinite time in the midst of putrefying matter, and subjected it to various other tests. After keeping the spore-charged blood which had been treated in this fashion for four years, he inoculated a number of mice with it, and found its action as fatal as that of blood fresh from the veins of an animal suffering from splenic fever. There was no single escape from death after inoculation by this deadly contagium. Uncounted millions of these spores are developed in the body of every animal which has died of splenic fever, and every spore of these millions is competent to produce the disease. The name of this formidable parasite is *Bacillus anthracis*.[1]

Now the very first step towards the extirpation of these contagia is the knowledge of their nature; and the knowledge brought to us by Dr. Koch will render as certain the stamping out of splenic fever as the stoppage of the plague of *pébrine* by the researches of Pasteur.[2] One small item of statistics will show what this implies. In the single district of Novgorod in Russia, between the years 1867 and 1870, over fifty-six thousand cases of death by splenic fever, among horses, cows, and sheep were recorded. Nor did its ravages confine themselves to the animal world, for during the time and in the district referred to, five hundred and twenty-eight human beings perished in the agonies of the same disease.

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[1] Koch found that to produce its characteristic effects the contagium of splenic fever must enter the blood; the virulently infective spleen of a diseased animal may be eaten with impunity by mice. On the other hand, the disease refuses to be communicated by inoculation to dogs, partridges, or sparrows. In their blood *Bacillus anthracis* ceases to act as a ferment. Pasteur announced more than six years ago the propagation of the vibrios of the silkworm disease called *flacherie*, both by fission and by spores. He also made some remarkable experiments on the permanence of the contagium in the form of spores. See 'Études sur la Maladie des Vers à Soie,' pp. 168 and 256.

[2] Surmising that the immunity enjoyed by birds might arise

A description of the fever will help you to come to a right decision on the point which I wish to submit to your consideration. 'An animal,' says Dr. Burdon Sanderson, 'which perhaps for the previous day has declined food and shown signs of general disturbance, begins to shudder and to have twitches of the muscles of the back, and soon after becomes weak and listless. In the meantime the respiration becomes frequent and often difficult, and the temperature rises three or four degrees above the normal; but soon convulsions, affecting chiefly the muscles of the back and loins, usher in the final collapse of which the progress is marked by the loss of all power of moving the trunk or extremities, diminution of temperature, mucous and sanguinolent alvine evacuations, and similar discharges from the mouth and nose.' In a single district of Russia, as above remarked, fifty-six thousand horses, cows, and sheep, and five hundred and twenty-eight men and women, perished in this way during a period of two or three years. What the annual fatality is throughout Europe I have no means of knowing. Doubtless it must be very great. The question, then,

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from the heat of their blood, which destroyed the *bacillus*, Pasteur lowered their temperature artificially, inoculated them, and *killed them*. He also raised the temperature of guinea-pigs after inoculation, and *saved them*. It is needless to dwell for a moment on the importance of this experiment.

which I wish to submit to your judgment is this:—Is the knowledge which reveals to us the nature, and which assures the extirpation, of a disorder so virulent and so vile, worth the price paid for it? It is exceedingly important that assemblies like the present should see clearly the issues at stake in such questions as this, and that the properly informed sense of the community should temper, if not restrain, the rashness of those who, meaning to be tender, become agents of cruelty by the imposition of short-sighted restrictions upon physiological investigations. It is a modern instance of zeal for God, but not according to knowledge, the excesses of which must be corrected by an instructed public opinion.

And now let us cast a backward glance on the field we have traversed, and try to extract from our labours such further profit as they can yield. For more than two thousand years the attraction of light bodies by amber was the sum of human knowledge regarding electricity, and for more than two thousand years fermentation was effected without any knowledge of its cause. In science one discovery grows out of another, and cannot appear without its proper antecedent. Thus, before fermentation could be understood, the microscope had to be invented, and brought to a considerable degree of perfection. Note the growth of knowledge. Leeuwenhoek, in 1680, found yeast to be a mass of floating globules, but he had no notion that the globules were alive. This was proved in 1835 by Cagniard de la Tour and Schwann. Then came the question as to the origin of such microscopic organisms, and in this connection the memoir of Pasteur, published in the 'Annales de Chimie' for 1862, is the inauguration of a new epoch.

On that investigation all Pasteur's subsequent labours were based. Ravages had over and over again occurred among French wines. There was no guarantee that they would not become acid or bitter, particularly when exported. The commerce in wines was thus restricted, and disastrous losses were often inflicted on the wine-grower. Every one of these diseases was traced to the life of an organism. Pasteur ascertained the temperature which killed these ferments of disease, proving it to be so low as to be perfectly harmless to the wine. By the simple expedient of heating the wine to a temperature of fifty degrees Centigrade, he rendered it inalterable, and thus saved his country the loss of millions. He then went on to vinegar—*vin aigre*, acid wine—which he proved to be produced by a fermentation set up by a little fungus called *Mycoderma aceti*. *Torula*, in fact, converts the grape juice into alcohol, and *Mycoderma aceti* converts the alcohol into vinegar. Here also frequent failures occurred, and severe losses were sustained. Through the operation of unknown causes, the vinegar often became unfit for use, sometimes indeed falling into utter putridity. It had been long known that mere exposure to the air was sufficient to destroy it. Pasteur studied all these changes, traced them to their living causes, and showed that the permanent health of the vinegar was ensured by the destruction of this life. He passed from the diseases of vinegar to the study of a malady which a dozen years ago had all but ruined the silk husbandry of France. This plague, which received the name of *pébrine*, was the product of a parasite which first took possession of the intestinal canal of the silkworm, spread throughout its body, and filled the sack which ought to contain the viscid matter of the silk. Thus smitten, the worm would go automatically through the process of spinning when it had nothing to spin.

Pasteur followed this parasitic destroyer from year to year, and led by his singular power of combining facts with the logic of facts, discovered eventually the precise phase in the development of the insect when the disease which assailed it could with certainty be stamped out. Pasteur's devotion to this enquiry cost him dear. He restored to France her silk husbandry, rescued thousands of her population from ruin, set the looms of Italy also to work, but emerged from his labours with one of his sides permanently paralysed. His last investigation is embodied in a work entitled 'Studies on Beer,' in which he describes a method of rendering beer permanently unchangeable. That method is not so simple as those found effectual with wine and vinegar, but the principles which it involves are sure to receive extensive application at some future day.

There are other reflections connected with this subject which, even were they now passed over without remark, would sooner or later occur to every thoughtful mind in this assembly. I have spoken of the floating dust of the air, of the means of rendering it visible, and of the perfect immunity from putrefaction which accompanies the contact of germless infusions and moteless air. Consider the woes which these wafted particles, during historic and pre-historic ages, have inflicted on mankind; consider the loss of life in hospitals from putrefying wounds; consider the loss in places where there are plenty of wounds, but no hospitals, and in the ages before hospitals were anywhere founded; consider the slaughter which has hitherto followed that of the battle-field, when those bacterial destroyers are let loose, often producing a mortality far greater than that of the battle itself; add to this the other conception that in times of epidemic disease the self-same floating matter has frequently, if not always, mingled with it the special germs which produce the epidemic, being thus enabled to sow pestilence and death over nations and continents —consider all this, and you will come with me to the conclusion that all the havoc of war, ten times multiplied, would be evanescent if compared with the ravages due to atmospheric dust.

This preventible destruction is going on to-day, and it has been permitted to go on for ages, without a whisper of information regarding its cause being vouchsafed to the suffering sentient world. We have been scourged by invisible thongs, attacked from impenetrable ambuscades, and it is only to-day that the light of science is being let in upon the murderous dominion of our foes. Facts like these excite in me the thought that the rule and governance of this universe are different from what we in our youth supposed them to be—that the inscrutable Power, at once terrible and beneficent, in whom we live and move and have our being and our end, is to be propitiated by means different to those usually resorted to. The first requisite towards such propitiation is *knowledge*; the second is *action*, shaped and illuminated by that knowledge. Of knowledge we already see the dawn, which will open out by-and-by to perfect day; while the action which is to follow has its unfailing source and stimulus in the moral and emotional nature of man—in his desire for personal well-being, in his sense of duty, in his compassionate sympathy with the sufferings of his fellow-men. 'How often,' says Dr. William Budd in his celebrated work on Typhoid Fever,—'How often have I seen in past days, in the single narrow chamber of the day-labourer's cottage the father in the coffin, the mother in the sick-bed in muttering delirium, and nothing to relieve the desolation of the children but the devotion of some poor neighbour, who in too many cases paid the penalty of her kindness in becoming herself the victim of the same disorder!' From the vantage ground already won I look forward with confident hope to the triumph of medical art over scenes of misery like that here described. The cause of the calamity being once clearly revealed, not only to the physician, but to the public, whose intelligent co-operation is absolutely essential to success, the final victory of humanity is only a question of time. We have already a foretaste of that victory in the triumphs of surgery as practised at your doors.

XIII.

SPONTANEOUS GENERATION.[1]

WITHIN ten minutes' walk of a little cottage which I have recently built in the Alps, there is a small lake, fed by the melted snows of the upper mountains. During the early weeks of summer no trace of life is to be discerned in this water; but invariably towards the end of July, or the beginning of August, swarms of tailed organisms are seen enjoying the sun's warmth along the shallow margins of the lake, and rushing with audible patter into deeper water at the approach of danger. The origin of this periodic crowd of living things is by no means obvious. For years I had never noticed in the lake either an adult frog, or the smallest fragment of frog spawn; so that were I not otherwise informed, I should have found the conclusion of Mathiole a natural one, namely, that tadpoles are generated in lake mud by the vivifying action of the sun.

The checks which experience alone can furnish being absent, the spontaneous generation of creatures quite as high as the frog in the scale of being was assumed for ages to be a fact. Here, as elsewhere, the dominant mind of Aristotle stamped its notions on the world at large. For nearly twenty centuries after him men found no difficulty in believing in cases of spontaneous generation which would now be rejected as monstrous by the most fanatical supporter of the doctrine. Shell-fish of all kinds were considered to be without parental origin. Eels were supposed to spring spontaneously from the fat ooze of the Nile. Caterpillars were the spontaneous products of the leaves on which they fed; while winged insects, serpents, rats, and mice were all thought capable of being generated without sexual intervention.

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[1] *The Nineteenth Century*, January 1878.

The most copious source of this life without an ancestry was putrefying flesh; and, lacking the checks imposed by fuller investigation, the conclusion that flesh possesses and exerts this generative power is a natural one. I well remember when a child of ten or twelve seeing a joint of imperfectly salted beef cut into, and coils of maggots laid bare within the mass. Without a moment's hesitation I jumped to the conclusion that these maggots had been spontaneously generated in the meat. I had no knowledge which could qualify or oppose this conclusion, and for the time it was irresistible. The childhood of the individual typifies that of the race, and the belief here enunciated was that of the world for nearly two thousand years.

To the examination of this very point the celebrated Francesco Redi, physician to the Grand Dukes Ferdinand II. and Cosmo III. of Tuscany, and a member of the Academy del Cimento, addressed himself in 1668. He had seen the maggots of putrefying flesh, and reflected on their possible origin. But he was not content with mere reflection, nor with the theoretic guesswork which his predecessors had founded upon their imperfect observations. Watching meat during its passage from freshness to decay, prior to the appearance of maggots he invariably observed flies buzzing round the meat and frequently alighting on it. The maggots, he thought, might be the half-developed progeny of these flies.

The inductive guess precedes experiment, by which, however, it must be finally tested. Redi knew this, and acted accordingly. Placing fresh meat in a jar and covering the mouth with paper, he found that, though the meat putrefied in the ordinary way, it never bred maggots, while the same meat placed in open jars soon swarmed with these organisms. For the paper cover he then substituted fine gauze, through which the odour of the meat could rise. Over it the flies buzzed, and on it they laid their eggs, but, the meshes being too small to permit the eggs to fall through, no maggots were generated in the meat. They were, on the contrary, hatched upon the gauze. By a series of such experiments Redi destroyed the belief in the spontaneous generation of maggots in meat, and with it doubtless many related beliefs. The combat was continued by Vallisneri, Schwammerdam, and Réaumur, who succeeded in banishing the notion of spontaneous generation from the scientific minds of their day. Indeed, as regards such complex organisms as those which formed the subject of their researches, the notion was banished for ever.

But the discovery and improvement of the microscope, though giving a death-blow to much that had been previously written and believed regarding spontaneous generation, brought also into view a world of life formed of individuals so minute— so close as it seemed to the ultimate particles of matter—as to suggest an easy passage from atoms to organisms. Animal and vegetable infusions exposed to the air were found clouded and crowded with creatures far beyond the reach of unaided vision, but perfectly visible to an eye strengthened by the microscope. With reference to their origin these organisms were called 'Infusoria. Stagnant pools were found full of them, and the obvious difficulty of assigning a germinal origin to existences so minute furnished the precise condition necessary to give new play to the notion of heterogenesis or spontaneous generation.

The scientific world was soon divided into two hostile camps, the leaders of which only can here be briefly alluded to. On the one side, we have Buffon and Needham, the former postulating his 'organic molecules,' and the latter assuming the existence of a special 'vegetative force' which drew the molecules together so as to form living things. On the other side, we have the celebrated Abbé Lazzaro Spallanzani, who in 1777 published results counter to those announced by Needham in 1748, and obtained by methods so precise as to completely overthrow the convictions based upon the labours of his predecessor. Charging his flasks with organic infusions, he sealed their necks with the blowpipe, subjected them in this condition to the heat of boiling water, and subsequently exposed them to temperatures favourable to the development of life. The infusions continued unchanged for months, and when the flasks were subsequently opened no trace of life was found.

Here I may forestall matters so far as to say that the success of Spallanzani's experiments depended wholly on the locality in which he worked. The air around him must have been free from the more obdurate infusorial germs, for otherwise the process he followed would, as was long afterwards proved by Wyman, have infallibly yielded life. But his refutation of the doctrine of spontaneous generation is not the less valid on this account. Nor is it in any way upset by the fact, that others in repeating his experiments obtained life where he obtained none. Rather is the refutation strengthened by such differences. Given two experimenters equally skilful and equally careful, operating in different places on the same infusion, in the same way, and assuming the one to obtain life while the other fails to obtain it; then its well-established absence in the one case proves that some ingredient foreign to the infusion must be its cause in the other.

Spallanzani's sealed flasks contained but small quantities of air, and as oxygen was afterwards shown to be generally essential to life, it was thought that the absence of life observed by Spallanzani might have been due to the lack of this vitalising gas. To dissipate this doubt, Schulze in 1836 half filled a flask with distilled water to which animal and vegetable matters were added. First boiling his infusion to destroy whatever life it might contain, Schulze sucked daily into his flask air which had passed through a series of bulbs containing concentrated sulphuric acid, where all germs of life suspended in the air were supposed to be destroyed. From May to August this process was continued without any development of infusorial life.

Here again the success of Schulzé was due to his working in comparatively pure air, but even in such air his experiment is a very risky one. Germs will pass unwetted and unscathed through sulphuric acid unless the most special care is taken to detain them. I have repeatedly failed, by repeating Schulze's experiments, to obtain his results. Others have failed likewise. The air passes in bubbles through the bulbs, and to render the method secure, the passage of the air must be so slow as to cause the whole of its floating matter, even to the very core of each bubble, to touch the surrounding liquid. But if this precaution be observed, water will be found quite as effectual as sulphuric acid. By the aid of an air-pump, in a highly infective atmosphere I have thus drawn air for weeks without intermission, first through bulbs containing water, and afterwards through vessels containing organic infusions, without any appearance of life. The germs were not killed by the water, but they were effectually intercepted, while the objection that the air had been injured by being brought into contact with strongly corrosive substances was avoided.

The brief paper of Schulze, published in Poggendorf's *Annalen* for 1836, was followed in 1837 by another short and pregnant communication by Schwann. Redi, as we have seen, traced the maggots of putrefying flesh to the eggs of flies. But he did not and he could not know the meaning of putrefaction itself. He had not the instrumental means to inform him that *it* also is a phenomenon attendant on the development of life. This was first proved in the paper now alluded to. Schwann placed flesh in a flask filled to one-third of its capacity with water, sterilised the flask by boiling, and then supplied it for months with calcined air. Throughout this time there appeared no mould, no infusoria, no putrefaction; the flesh remained unaltered, while the liquid continued as clear as it was immediately after boiling. Schwann then varied his experimental argument, with no alteration in the result. His final conclusion was, that putrefaction is due to decompositions of organic matter attendant on the multiplication therein of minute organisms. These organisms were derived not from the air, but from something contained in the air, which was destroyed by a sufficiently high temperature. There never was a more determined opponent of the doctrine of spontaneous generation than Schwann, though a strange attempt was made a year and a half ago to enlist him and others equally opposed to it on the side of the doctrine.

The physical character of the agent which produces putrefaction was further revealed by Helmholtz in 1843. By means of a membrane he separated a sterilised putrescible liquid from a putrefying one. The sterilised infusion remained perfectly intact. Hence it was not the liquid of the putrefying mass—for that could freely diffuse through the membrane—but something contained in the liquid, and which was stopped by the membrane, that caused the putrefaction. In 1854 Schroeder and Von Dusch struck into this enquiry, which was subsequently followed up by Schroeder alone. These able experimenters employed plugs of cotton-wool to filter the air supplied to their infusions. Fed with such air, in the great majority of cases the putrescible liquids remained perfectly sweet after boiling. Milk formed a conspicuous exception to the general rule. It putrefied after boiling, though supplied with carefully filtered air. The researches of Schroeder bring us up to the year 1859.

In that year a book was published which seemed to overturn some of the best established facts of previous investigators. Its title was *Hétérogénie*, and its author was F. A. Pouchet, Director of the Museum of Natural History at Rouen. Ardent, laborious, learned, full not only of scientific but of metaphysical fervour, he threw his whole energy into the enquiry. Never did a subject require the exercise of the cold critical faculty more than this one—calm study in the unravelling of complex phenomena, care in the preparation of experiments, care in their execution, skilful variation of conditions, and incessant questioning of results until repetition had placed them beyond doubt or question. To a man of Pouchet's temperament the subject was full of danger

—danger not lessened by the theoretic bias with which he approached it. This is revealed by the opening words of his preface: 'Lorsque, par la méditation, il fut évident pour moi que la génération spontanée était encore l'un des moyens qu'emploie la nature pour la reproduction des êtres, je m'appliquai à découvrir par quels procédés on pouvait parvenir à en mettre les phénomènes en évidence.' It is needless to say that such a prepossession required a strong curb. Pouchet repeated the experiments of Schulze and Schwann with results diametrically opposed to theirs. He heaped experiment upon experiment and argument upon argument, spicing with the sarcasm of the advocate the logic of the man of science. In view of the multitudes required to produce the observed results, he ridiculed the assumption of atmospheric germs. This was one of his strongest points. 'Si les Proto-organismes que nous voyons pulluler partout et dans tout, avaient leurs germes disséminés dans l'atmosphère, dans la proportion mathématiquement indispensable à cet effet, l'air en serait totalement obscurci, car ils devraient s'y trouver beaucoup plus serrés que les globules d'eau qui forment nos nuages épais. Il n'y a pas là la moindre exagération.' Recurring to the subject, he exclaims: 'L'air dans lequel nous vivons aurait presque la densité du fer.' There is often a virulent contagion in a confident tone, and this hardihood of argumentative assertion was sure to influence minds swayed not by knowledge, but by authority. Had Pouchet known that 'the blue ethereal sky' is formed of suspended particles, through which the sun freely shines, he would hardly have ventured upon this line of argument.

Pouchet's pursuit of this enquiry strengthened the conviction with which he began it, and landed him in downright credulity in the end. I do not question his ability as an observer, but the enquiry needed a disciplined experimenter. This latter implies not mere ability to look at things as Nature offers them to our inspection, but to force her to show herself under conditions prescribed by the experimenter himself. Here Pouchet lacked the necessary discipline. Yet the vigour of his onset raised clouds of doubt, which for a time obscured the whole field of enquiry. So difficult indeed did the subject seem, and so incapable of definite solution, that when Pasteur made known his intention to take it up, his friends Biot and Dumas expressed their regret, earnestly exhorting him to set a definite and rigid limit to the time he purposed spending in this apparently unprofitable field.[1]

Schooled by his education as a chemist, and by special researches on the closely related question of fermentation, Pasteur took up this subject under particularly favourable conditions. His work and his culture had given strength and finish to his natural aptitudes. In 1862, accordingly, he published a paper 'On the Organised Corpuscles existing in the Atmosphere,' which must for ever remain classical. By the most ingenious devices he collected the floating particles of the air surrounding his laboratory in the Rue d'Ulm, and subjected them to microscopic examination. Many of them he found to be organised particles. Sowing them in sterilised infusions, he obtained abundant crops of microscopic organisms. By more refined methods he repeated and confirmed the experiments of Schwann, which had been contested by Pouchet, Montegazza, Joly, and Musset. He also confirmed the experiments of Schroeder and Von Dusch. He showed that the cause which communicated life to his infusions was not uniformly diffused through the air; that there were aërial interspaces which possessed no power to generate life. Standing on the Mer de Glace, near the Montanvert, he snipped off the ends of a number of hermetically sealed flasks containing organic infusions. One out of twenty of the flasks thus supplied with glacier air showed signs of life afterwards, while eight out of twenty of the same infusions, supplied with the air of the plains, became crowded with life. He took his flasks into the caves under the Observatory of Paris, and found the still air in these caves devoid of generative power. These and other experiments, carried out with a severity perfectly obvious to the instructed scientific reader, and accompanied by a logic equally severe, restored the conviction that, even in these lower reaches of the scale of being, life does not appear without the operation of antecedent life.

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[1] 'Je ne conseillerais à personne,' said Dumas to his already famous pupil, 'de rester trop longtemps dans ce sujet.'—*Annales de Chimie et de Physique*, 1862, vol. lxiv. p. 22. Since that time the illustrious Perpetual Secretary of the Academy of Sciences has had good reason to revise this 'counsel.'

The main position of Pasteur has been strengthened by practical researches of the most momentous kind. He has applied the knowledge won from his enquiries to the preservation of wine and beer, to the manufacture of vinegar, to the staying of the plague which threatened utter destruction of the silk husbandry of France, and to the examination of other formidable diseases which assail the higher animals, including man. His relation to the improvements which Professor Lister has introduced into surgery, is shown by a letter quoted in his *Etudes sur la Bière.*[1] Professor Lister there expressly thanks Pasteur for having given him the only principle which could have conducted the antiseptic system to a successful issue. The strictures regarding defects of reasoning, to which we have been lately accustomed, throw abundant light upon their author, but no shade upon Pasteur.

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[1] P. 43.

Redi, as we have seen, proved the maggots of putrefying flesh to be derived from the eggs of flies; Schwann proved putrefaction itself to be the concomitant of far lower forms of life than those dealt with by Redi. Our knowledge here, as elsewhere in connection with this subject, has been vastly extended by Professor Cohn, of Breslau. 'No putrefaction,' he says, 'can occur in a nitrogenous substance if its bacteria be destroyed and new ones prevented from entering it. Putrefaction begins as soon as bacteria, even in the smallest numbers, are admitted either accidentally or purposely. It progresses in direct proportion to the multiplication of the bacteria, it is retarded when they exhibit low vitality, and is stopped by all influences which either hinder their development or kill them. All bactericidal media are therefore antiseptic and disinfecting.'[1] It was these organisms acting in wound and abscess which so frequently converted our hospitals into charnel-houses, and it is their destruction by the antiseptic system that now renders justifiable operations which no surgeon would have attempted a few years ago. The gain is immense—to the practising surgeon as well as to the patient practised upon. Contrast the anxiety of never feeling sure whether the most brilliant operation might not be rendered nugatory by the access of a few particles of unseen hospital dust, with the comfort derived from the knowledge that all power of mischief on the part of such dust has been surely and certainly annihilated. But the action of living contagia extends beyond the domain of the surgeon. The power of reproduction and indefinite self-multiplication which is characteristic of living things, coupled with the undeviating fact of contagia 'breeding true,' has given strength and consistency to a belief long entertained by penetrating minds, that epidemic diseases generally are the concomitants of parasitic life. 'There begins to be faintly visible to us a vast and destructive laboratory of nature wherein the diseases which are most fatal to animal life, and the changes to which dead organic matter is passively liable, appear bound together by what must at least be called a very close analogy of causation.'[1] According to this view, which, as I have said, is daily gaining converts, a contagious disease may be defined as a conflict between the person smitten by it and a specific organism which multiplies at his expense, appropriating his air and moisture, disintegrating his tissues, or poisoning him by the decompositions incident to its growth.

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[1] In his last excellent memoir Cohn expresses himself thus: 'Wer noch heut die Fäulniss von einer spontanen Dissociation der Proteinmolecule, oder von einem unorganisirten Ferment ableitet, oder gar aus "Stickstoffsplittern" die Balken zur Stütze seiner Fäulnisstheorie zu zimmern versucht, hat zuerst den Satz "keine Fäulniss ohne Bacterium Termo" zu widerlegen.'

During the ten years extending from 1859 to 1869, researches on radiant heat in its relations to the gaseous form of matter occupied my continual attention. When air was experimented on, I had to cleanse it effectually of floating matter, and while doing so I was surprised to notice that, at the ordinary rate of transfer, such matter passed freely through alkalis, acids, alcohols, and ethers. The eye being kept sensitive by darkness, a concentrated beam of light was found to be a most searching test for suspended matter both in water and in air—a test indeed indefinitely more searching and severe than that furnished by the most powerful microscope. With the aid of such a beam I examined air filtered by cotton-wool; air long kept free from agitation, so as to allow the floating matter to subside; calcined air, and air filtered by the deeper cells of the human lungs. In all cases the correspondence between my experiments and those of Schroeder, Pasteur, and Lister in regard to spontaneous generation was perfect. The air which they found inoperative was proved by the luminous beam to be optically pure and therefore germless. Having worked at the subject both by experiment and reflection, on Friday evening, January 21, 1870, I brought it before the members of the Royal Institution. Two or three months subsequently, for sufficient practical reasons, I ventured to direct public attention to the subject in a letter to the *Times*. Such was my first contact with this important question.

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[1] Report of the Medical Officer of the Privy Council, 1874, p. 5.

This letter, I believe, gave occasion for the first public utterance of Dr. Bastian in relation to this subject. He did me the honour to inform me, as others had informed Pasteur, that the subject 'pertains to the biologist and physician.' He expressed 'amazement' at my reasoning, and warned me that before what I had done could be undone 'much irreparable mischief might be occasioned.' With far less preliminary experience to guide and warn him, the English heterogenist was far bolder than Pouchet in his experiments, and far more adventurous in his conclusions. With organic infusions he obtained the results of his celebrated predecessor, but he did much more—the atoms and molecules of inorganic liquids passing under his manipulation into those more 'complex chemical compounds,' which we dignify by calling them 'living organisms.'[1] As regards the public who take an interest in such things, and apparently also as regards a large portion of the medical profession, our clever countryman succeeded in restoring the subject to a state of uncertainty similar to that which followed the publication of Pouchet's volume in 1859.

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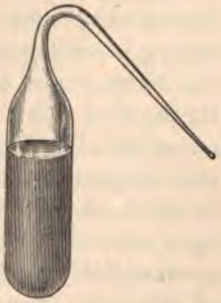
[1] 'It is further held that bacteria or allied organisms are prone to be engendered as correlative products, coming into existence in the several fermentations, just as independently as other less complex chemical compounds.'—Bastian, *Trans. of Pathological Society*, vol. xxvi. 258.

It is desirable that this uncertainty should be removed from all minds, and doubly desirable on practical grounds that it should be removed from the minds of medical men. In the present article, therefore, I propose discussing this question face to face with some eminent and fair-minded member of the medical profession who, as regards spontaneous generation, entertains views adverse to mine. Such a one it would be easy to name; but it is perhaps better to rest in the impersonal. I shall therefore simply call my proposed co-enquirer my friend. With him at my side, I shall endeavour, to the best of my ability, so to conduct this discussion that he who runs may read and that he who reads may understand.

Let us begin at the beginning. I ask my friend to step into the laboratory of the Royal Institution, where I place before him a basin of thin turnip slices barely covered with distilled water kept at a temperature of 120° Fahr. After digesting the turnip for four or five hours we pour off the liquid, boil it, filter it, and obtain an infusion as clear as filtered drinking water. We cool the infusion, test its specific gravity, and find it to be 1006 or higher —water being 1000. A number of small clean empty flasks, of the shape shown on the margin, are before us. One of them



is slightly warmed with a spirit-lamp, and its open end is then dipped into the turnip infusion. The warmed glass is afterwards chilled, the air within the flasks cools, contracts, and is followed in its contraction by the infusion. Thus we get a small quantity of liquid into the flask. We now heat this liquid carefully. Steam is produced, which issues from the open neck, carrying the air of the flask along with it. After a few seconds' ebullition, the open neck is again plunged into the infusion. The steam within the flask condenses, the liquid enters to supply its place, and in this way we fill our little flask to about four-fifths of its volume. This description is typical; we may thus fill a thousand flasks with a thousand different infusions.

I now ask my friend to notice a trough made of sheet copper, with two rows of handy little Bunsen burners underneath it. This trough, or bath, is nearly filled with oil; a piece of thin plank constitutes a kind of lid for the oil-bath. The wood is perforated with circular apertures wide enough to allow our small flask to pass through and plunge itself in the oil, which has been heated, say, to 250° Fahr. Clasped all round by the hot liquid, the infusion in the flask rises to its boiling point, which is not sensibly over 212° Fahr. Steam issues from the open neck of the flask, and the boiling is continued for five minutes. With a pair of small brass tongs, an assistant now seizes the neck near its junction with the flask, and partially lifts the latter out of the oil. The steam does not cease to issue, but its violence is abated. With a second pair of tongs held in one hand, the neck of the flask is seized close to its open end, while with the other hand a Bunsen's flame or an ordinary spirit flame is brought under the middle of the neck. The glass reddens, whitens, softens, and as it is gently drawn out the neck diminishes in diameter, until the canal is completely blocked up. The tongs with the fragment of severed neck being withdrawn, the flask, with its contents diminished by evaporation, is lifted from the oil-bath perfectly sealed hermetically.

Sixty such flasks filled, boiled, and sealed in the manner described, and containing strong infusions of beef, mutton, turnip, and cucumber, are carefully packed in sawdust, and transported to the Alps. Thither, to an elevation of about 7,000 feet above the sea, I invite my co-enquirer to accompany me. It is the month of July, and the weather is favourable to putrefaction. We open our box at the Bel-Alp, and count out fifty-four flasks, with their liquids as clear as filtered drinking water. In six flasks, however, the infusion is found muddy. We closely examine these, and discover that every one of them has had its fragile end broken off in the transit from London. Air has entered the flasks, and the observed muddiness is the result. My colleague knows as well as I do what this means. Examined with a pocket-lens, or even with a microscope of insufficient power, nothing is seen in the muddy liquid; but regarded with a magnifying power of a thousand diameters or so, what an astonishing appearance does it present! Leeuwenhoek estimated the population of a single drop of stagnant water at 500,000,000: probably the population of a drop of our turbid infusion would be this many times multiplied. The field of the microscope is crowded with organisms, some wabbling slowly, others shooting rapidly across the microscopic field. They dart hither and thither like a rain of minute projectiles; they pirouette and spin so quickly round, that the retention of the retinal impression transforms the little living rod into a twirling wheel. And yet the most celebrated naturalists tell us they are vegetables. From the rod-like shape which they so frequently assume, these organisms are called 'bacteria'—a term, be it here remarked, which covers organisms of very diverse kinds.

Has this multitudinous life been spontaneously generated in these six flasks, or is it the progeny of living germinal matter carried into the flasks by the entering air? If the infusions have a self-generative power, how are the sterility and consequent clearness of the fifty-four uninjured flasks to be accounted for? My colleague may urge—and fairly urge—that the assumption of germinal matter is by no means necessary; that the air itself may be the one thing needed to wake up the dormant infusions. We will examine this point immediately. But meanwhile I would remind him that I am working on the exact lines laid down by our most conspicuous heterogenist. He distinctly affirms that the withdrawal of the atmospheric pressure above the infusion favours the production of organisms; and he accounts for their absence in tins of preserved meat, fruit, and vegetables, by the hypothesis that fermentation *has* begun in such tins, that gases *have* been generated, the pressure of which has stifled the incipient life and stopped its further development.[1] This is the new theory of preserved meats. Had its author pierced a tin of preserved meat, fruit, or vegetable under water with the view of testing its truth, he would have found it erroneous. In well-preserved tins he would have found, not an outrush of gas, but an inrush of water. I have noticed this recently in tins which have lain perfectly good for sixty-three years in the Royal Institution. Modern tins, subjected to the same test, yielded the same result. From time to time, moreover, during the last two years, I have placed glass tubes, containing clear infusions of turnip, hay, beef, and mutton, in iron bottles, and subjected them to air-pressures varying from ten to twenty-seven atmospheres—pressures, it is needless to say, far more than sufficient to tear a preserved meat tin to shreds. After ten days these infusions were taken from their bottles rotten with putrefaction and teeming with life. Thus collapses an hypothesis which had no rational foundation, and which could never have seen the light had the slightest attempt been made to verify it.

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[1] *Beginnings of Life*, vol. i. p. 418.

Our fifty-four vacuous and pellucid flasks also declare against the heterogenist. We expose them to a warm Alpine sun by day, and at night we suspend them in a warm kitchen. Four of them have been accidentally broken; but at the end of a month we find the fifty remaining ones as clear as at the commencement. There is no sign of putrefaction or of life in any of them. We divide these flasks into two groups of twenty-three and twenty-seven respectively (an accident of counting rendered the division uneven). The question now is whether the admission of air can liberate any generative energy in the infusions. Our next experiment will answer this question and something more. We carry the flasks to a hayloft, and there, with a pair of steel pliers, snip off the sealed ends of the group of three-and-twenty. Each snipping off is of course followed by an inrush of air. We now carry our twenty-seven flasks, our pliers, and a spirit-lamp, to a ledge overlooking the Aletsch glacier, about 200 feet above the hayloft, from which ledge the mountain falls almost precipitously to the north-east for about a thousand feet. A gentle wind blows towards us from the north-east—that is, across the crests and snow-fields of the Oberland mountains. We are therefore bathed by air which must have been for a good while out of practical contact with either animal or vegetable life. I stand carefully to leeward of the flasks, for no dust or particle from my clothes or body must be blown towards them. An assistant ignites the spirit-lamp, into the flame of which I plunge the pliers, thereby destroying all attached germs or organisms. Then I snip off the sealed end of the flask. Prior to every snipping the same process is gone through, no flask being opened without the previous cleansing of the pliers by the flame. In this way we charge our seven-and-twenty flasks with clean vivifying mountain air.

We place the fifty flasks, with their necks open, over a kitchen stove, in a temperature varying from 50° to 90° Fahr., and in three days find twenty-one out of the twenty-three flasks opened on the hayloft invaded by organisms—two only of the group remaining free from them. After three weeks' exposure to precisely the same conditions, not one of the twenty-seven flasks opened in free air had given way. No germ from the kitchen air had ascended the narrow necks, the flasks being shaped to produce this result. They are still in the Alps, as clear, I doubt not, and as free from life as they were when sent off from London.[1]

What is my colleague's conclusion from the experiment before us? Twenty-seven putrescible infusions, first in vacuo, and afterwards supplied with the most invigorating air, have shown no sign of putrefaction or of life. And as to the others, I almost shrink from asking him whether the hayloft has rendered them spontaneously generative. Is not the inference here imperative that it is not the air of the loft—which is connected through a constantly open door with the general atmosphere—but something contained in the air, that has produced the effects observed? What is this something? A sunbeam entering through a chink in the roof or wall, and traversing the air of the loft, would show it to be laden with suspended dust particles. Indeed the dust is distinctly visible in the diffused daylight. Can *it* have been the origin of the observed life? If so, are we not bound by all antecedent experience to regard these fruitful particles as the germs of the life observed?

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[1] An actual experiment made at the Bel Alp is here described.

The name of Baron Liebig has been constantly mixed up with these discussions. 'We have,' it is said, 'his authority for assuming that dead decaying matter can produce fermentation.' True, but with Liebig fermentation was by no means synonymous with *life*. It meant, according to him, the shaking asunder by chemical disturbance of unstable molecules. Does the life of our flasks, then, proceed from *dead* particles? If my co-enquirer should reply 'Yes,' then I would ask him, 'What warrant does Nature offer for such an assumption? Where, amid the multitude of vital phenomena in which her operations have been clearly traced, is the slightest countenance given to the notion that the sowing of dead particles can produce a living crop?' With regard to Baron Liebig, had he studied the revelations of the microscope in relation to these questions, a mind so penetrating could never have missed the significance of the facts revealed. He, however, neglected the microscope, and fell into error—but not into error so gross as that in support of which his authority has been invoked. Were he now alive, he would, I doubt not, repudiate the use often made of his name—Liebig's view of fermentation was at least a scientific one, founded on profound conceptions of molecular instability. But this view by no means involves the notion that the planting of dead particles

—'Stickstoffsplittern' as Cohn contemptuously calls them—is followed by the sprouting of infusorial life.

Let us now return to London and fix our attention on the dust of *its* air. Suppose a room in which the housemaid has just finished her work to be completely closed, with the exception of an aperture in a shutter through which a sunbeam enters and crosses the room. The floating dust reveals the track of the light. Let a lens be placed in the aperture to condense the beam. Its parallel rays are now converged to a cone, at the apex of which the dust is raised to almost unbroken whiteness by the intensity of its illumination. Defended from all glare, the eye is peculiarly sensitive to this scattered light. The floating dust of London rooms is organic, and may be burned without leaving visible residue. The action of a spirit-lamp flame upon the floating matter has been elsewhere thus described:—

> In a cylindrical beam which strongly illuminated the dust of our laboratory, I placed an ignited spirit-lamp. Mingling with the flame, and round its rim, were seen curious wreaths of darkness resembling an intensely black smoke. On placing the flame at some distance below the beam, the same dark masses stormed upwards. They were blacker than the blackest smoke ever seen issuing from the funnel of a steamer; and their resemblance to smoke was so perfect as to prompt the conclusion that the apparently pure flame of the alcohol-lamp required but a beam of sufficient intensity to reveal its clouds of liberated carbon.
>
> But is the blackness smoke? This question presented itself in a moment, and was thus answered: A red-hot poker was placed underneath the beam; from it the black wreaths also ascended. A large hydrogen flame, which emits no smoke, was next employed, and it also produced with augmented copiousness those whirling masses of darkness. Smoke being out of the question, what is the black-

ness? It is simply that of stellar space; that is to say, blackness resulting from the absence from the track of the beam of all matter competent to scatter its light. When the flame was placed below the beam, the floating matter was destroyed *in situ*; and the heated air, freed from this matter, rose into the beam, jostled aside the illuminated particles, and substituted for their light the darkness due to its own perfect transparency. Nothing could more forcibly illustrate the invisibility of the agent which renders all things visible. The beam crossed, unseen, the black chasm formed by the transparent air, while, at both sides of the gap, the thick-strewn particles shone out like a luminous solid under the powerful illumination.[1]

Supposing an infusion intrinsically barren, but readily susceptible of putrefaction when exposed to common air, to be brought into contact with this unilluminable air, what would be the result? It would never putrefy. It might, however, be urged that the air is spoiled by its violent calcination. Oxygen passed through a spirit-lamp flame is, it may be thought, no longer the oxygen suitable for the development and maintenance of life. We have an easy escape from this difficulty, which is based, however, upon the unproved assumption that the air has been affected by the flame. Let a condensed beam be sent through a large flask or bolthead containing common air. The track of the beam is seen within the flask—the dust revealing the light, and the light revealing the dust. Cork the flask, stuff its neck with cotton-wool, or simply turn it mouth downwards and leave it undisturbed for a day or two. Examined afterwards with the luminous beam, no track is visible; the light passes through the flask as through a vacuum. The floating matter has abolished itself, being now attached to the interior surface of the flask.

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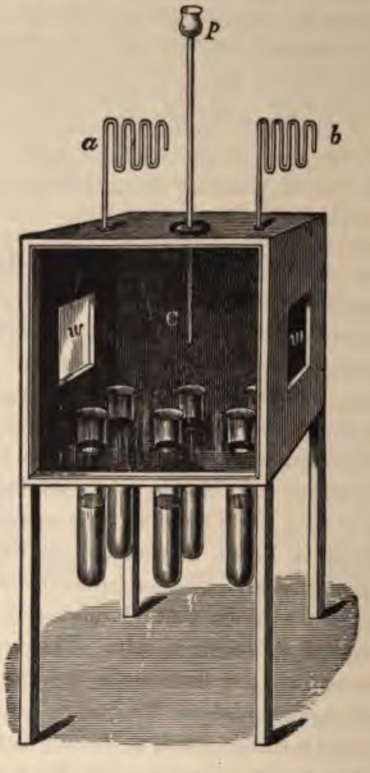
[1] See page 133, vol. i.

Were it our object, as it will be subsequently, to effectually detain the dirt, we might coat that surface with some sticky substance. Here, then, without 'torturing' the air in any way, we have found a means of ridding it, or rather of enabling it to rid itself, of floating matter.



We have now to devise a means of testing the action of such spontaneously purified air upon putrescible infusions. Wooden chambers, or cases, are accordingly constructed, having glass fronts, side-windows, and back-doors. Through the bottoms of the chambers test-tubes pass air-tight; their open ends, for about one-fifth of the length of the tubes, being within the chambers. Provision is made for a free connection through sinuous channels between the inner and the outer air. Through such channels, though open, no dust will reach the chamber. The top of each chamber is perforated by a circular hole two inches in diameter, closed air-tight by a sheet of india-rubber. This is pierced in the middle by a pin, and through the pin-hole is pushed the shank of a long pipette, ending above in a small funnel. The shank also passes through a stuffing-box of cotton-wool moistened with glycerine; so that, tightly clasped by the rubber and wool, the pipette is not likely in its motions up and down to carry any dust into the chamber. The annexed woodcut shows a chamber, with six test-tubes, its side-windows *w w*, its pipette *p* c, and its sinuous channels *a b* which connect the air of the chamber with the outer air.

The chamber is carefully closed and permitted to remain quiet for two or three days. Examined at the beginning by a beam sent through its windows, the air is found laden with floating matter, which in three days has wholly disappeared. To prevent its ever rising again, the internal surface of the chamber was at the outset coated with glycerine. The fresh but putrescible liquid is introduced into the six tubes in succession by means of the pipette. Permitted to remain without further precaution, every one of the tubes would putrefy and fill itself with life. The liquid has been in contact with the dust-laden air outside by which it has been infected, and the infection must be destroyed. This is done by plunging the six tubes into a bath of heated oil and boiling the infusion. The time requisite to destroy the infection depends wholly upon its nature. Two minutes' boiling suffices to destroy some contagia, whereas two hundred minutes' boiling fails to destroy others. After the infusion has been sterilised, the oil-bath is withdrawn, and the liquid, whose putrescibility has been in no way affected by the boiling, is abandoned to the air of the chamber.

With such chambers I tested, in the autumn and winter of 1875–6, infusions of the most various kinds, embracing natural animal liquids, the flesh and viscera of domestic animals, game, fish, and vegetables. More than fifty chambers, each with its series of infusions, were tested, many of them repeatedly. There was no shade of uncertainty in any of the results. In every instance we had, within the chamber, perfect limpidity and sweetness, which in some cases lasted for more than a year—without the chamber, with the same infusion, putridity and its characteristic smells. In no instance was the least countenance lent to the notion that an infusion deprived by heat of its inherent life, and placed in contact with air cleansed of its visibly suspended matter, has any power to generate life anew.

Remembering then the number and variety of the infusions employed, and the strictness of our adherence to the rules of preparation laid down by the heterogenists themselves; remembering that we have operated upon the very substances recommended by them as capable of furnishing, even in untrained hands, easy and decisive proofs of spontaneous generation, and that we have added to their substances many others of our own—if this pretended generative power were a reality, surely it must have manifested itself somewhere. Speaking roundly, I should say that in such closed chambers at least five hundred chances have been given to it, but it has nowhere appeared.

The argument is now to be clenched by an experiment which will remove every residue of doubt as to the ability of the infusions here employed to sustain life. We open the back doors of our sealed chambers, and permit the common air with its floating particles to have access to our tubes. For three months they have remained pellucid and sweet—flesh, fish, and vegetable extracts purer than ever cook manufactured. Three days' exposure to the dusty air suffices to render them muddy, fetid, and swarming with infusorial life. The liquids are thus proved, one and all, ready for putrefaction when the contaminating agent is applied. I invite my colleague to reflect on these facts. How will he account for the absolute immunity of a liquid exposed for months in a warm room to optically pure air, and its infallible putrefaction in a few days when exposed to dust-laden air? He must, I submit, bow to the conclusion that the dust-particles are the cause of putrefactive life. And unless he accepts the hypothesis that these particles, being dead in the air, are in the liquid miraculously kindled into living things, he must conclude that the life we have observed springs from germs or organisms diffused through the atmosphere.

The experiments with hermetically sealed flasks have reached the number of 940. A sample group of 130 of them were laid before the Royal Society on January 13, 1876. They were utterly free from life, having been completely sterilised by three minutes' boiling. Special care had been taken that the temperatures to which the flasks were exposed should include those previously alleged to be efficient. The conditions laid down by the heterogenist were accurately copied, but there was no corroboration of his results. Stress was then laid on the question of warmth, thirty degrees being suddenly added to the temperatures with which both of us had previously worked. Waiving all protest against the caprice thus manifested, I met this new requirement also. The sealed tubes, which had proved barren in the Royal Institution, were suspended in perforated boxes, and placed under the supervision of an intelligent assistant in the Turkish Bath in Jermyn Street. From two to six days had been allowed for the generation of organisms in hermetically sealed tubes. Mine remained in the washing-room of the bath for nine days. Thermometers placed in the boxes, and read off twice or three times a day, showed the temperature to vary from a minimum of 101° to a maximum of 112° Fahr. At the end of nine days the infusions were as clear as at the beginning. They were then removed to a warmer position. A temperature of 115° had been mentioned as particularly favourable to spontaneous generation. For fourteen days the temperature of the Turkish Bath hovered about this point, falling once as low as 106°, reaching 116° on three occasions, 118° on one, and 119° on two. The result was quite the same as that just recorded. The higher temperatures proved perfectly incompetent to develope life.

Taking the actual experiment we have made as a basis of calculation, if our 940 flasks were opened on the hayloft of the Bel Alp, 858 of them would become filled with organisms. The escape of the remaining 82 strengthens our case, proving as it does conclusively that not in the air, nor in the infusions, nor in anything continuous diffused through the air, but in *discrete particles*, suspended in the air and nourished by the infusions, we are to seek the cause of life. Our experiment proves these particles to be in some cases so far apart on the hayloft as to permit 10 per cent. of our flasks to take in air without contracting contamination. A quarter of a century ago Pasteur proved the cause of 'so-called spontaneous generation' to be *discontinuous*. I have already referred to his observation that 12 out of 20 flasks opened on the plains escaped infection, while 19 out of 20 flasks opened on the Mer de Glace escaped. Our own experiment at the Bel Alp is a more emphatic instance of the same kind, 90 per cent. of the flasks opened in the hayloft being smitten, while not one of those opened on the free mountain ledge was attacked.

The power of the air as regards putrefactive infection is incessantly changing through natural causes, and we are able to alter it at will. Of a number of flasks opened in 1876 in the laboratory of the Royal Institution, 42 per cent. were smitten, while 58 per cent. escaped. In 1877 the proportion in the same laboratory was 68 per cent. smitten, to 32 intact. The greater mortality, so to speak, of the infusions in 1877 was due to the presence of hay which diffused its germinal dust in the laboratory air, causing it to approximate as regards infective virulence to the air of the Alpine loft. I would ask my friend to bring his scientific penetration to bear upon all the foregoing facts. They do not prove spontaneous generation to be 'impossible.' My assertions, however, relate not to 'possibilities,' but to *proofs*, and the experiments just described do most distinctly prove the evidence on which the heterogenist relies to be written on waste paper.

My colleague will not, I am persuaded, dispute these results; but he may be disposed to urge that other able and honourable men working at the same subject have arrived at conclusions different from mine. Most freely granted; but let me here recur to the remarks already made in speaking of the experiments of Spallanzani, to the effect that the failure of others to confirm his results by no means upsets their evidence. To fix the ideas, let us suppose that my colleague comes to the laboratory of the Royal Institution, repeats there my experiments, and obtains confirmatory results; and that he then goes to University or King's College where, operating with the same infusions, he obtains contradictory results. Will he be disposed to conclude that the selfsame substance is barren in Albemarle Street and fruitful in Gower Street or the Strand? His Alpine experience has already made known to him the literally infinite differences existing between different samples of air as regards their capacity for putrefactive infection. And, possessing this knowledge, will he not substitute for the adventurous conclusion that an organic infusion is barren at one place and spontaneously generative at another, the more rational and obvious one that the atmospheres of the two localities which have had access to the infusion are infective in different degrees?

As regards workmanship, moreover, he will not fail to bear in mind, that *fruitfulness* may be due to errors of manipulation, while *barrenness* involves the presumption of correct experiment. It is only the careful worker that can secure the latter, while it is open to every novice to obtain the former. Barrenness is the result at which the conscientious experimenter, whatever his theoretic convictions may be, ought to aim, omitting no pains to secure it, and resorting only when there is no escape from it to the conclusion that the life observed comes from no source which correct experiment could neutralise or avoid.

Let us again take a definite case. Supposing my colleague to operate with the same apparent care on 100 infusions—or rather on 100 samples of the same infusion—and that 50 of them prove fruitful and 50 barren. Are we to say that the evidence for and against heterogeny is equally balanced? There are some who would not only say this, but who would treasure up the 50 fruitful flasks as 'positive' results, and lower the evidential value of the 50 barren flasks by labelling them 'negative' results. This, as shown by Dr. William Roberts, is an exact inversion of the true order of the terms positive and negative.[1] Not such, I trust, would be the course pursued by my friend. As regards the 50 fruitful flasks he would, I doubt not, repeat the experiment with redoubled care and scrutiny, and not by one repetition only, but by many, assure himself that he had not fallen into error. Such faithful scrutiny fully carried out would infallibly lead him to the conclusion that here, as in all other cases, the evidence in favour of spontaneous generation crumbles in the grasp of the competent enquirer.

The botanist knows that different seeds possess different powers of resistance to heat.[2] Some are killed by a momentary exposure to the boiling temperature, while others withstand it for several hours. Most of our ordinary seeds are rapidly killed, while Pouchet made known to the Paris Academy of Sciences in 1866, that certain seeds, which had been transported in fleeces of wool from Brazil, germinated after four hours' boiling. The germs of the air vary as much among themselves as the seeds of the botanist. In some localities the diffused germs are so tender that boiling for five minutes, or even less, would be sure to destroy them all; in other localities the diffused germs are so obstinate, that many hours' boiling would be requisite to deprive them of their power of germination. The absence or presence of a truss of desiccated hay would produce differences as great as those here described. The greatest endurance that I have ever observed—and I believe it is the greatest on record—was a case of survival after eight hours' boiling.

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[1] See his truly philosophical remarks on this head in the 'British Medical Journal,' 1876, p. 282.

[2] I am indebted to Dr. Thiselton Dyer for various illustrations of such differences. It is, however, surprising that a subject of such high scientific importance should not have been more thoroughly explored. Here the scoundrels who deal in killed seeds might be able to add to our knowledge.

As regards their power of resisting heat, the infusorial germs of our atmosphere might be classified under the following and intermediate heads:—Killed in five minutes; not killed in five minutes but killed in fifteen; not killed in fifteen minutes but killed in thirty; not killed in thirty minutes but killed in an hour; not killed in an hour but killed in two hours; not killed in two but killed in three hours; not killed in three but killed in four hours. I have had several cases of survival after four and five hours' boiling, some survivals after six, and one after eight hours' boiling. Thus far has experiment actually reached; but there is no valid warrant for fixing upon even eight hours as the extreme limit of vital resistance. Probably more extended researches (though mine have been very extensive) would reveal germs more obstinate still. It is also certain that we might begin earlier, and find germs which are destroyed by a temperature far below that of boiling water. In the presence of such facts, to speak of *a* death-point of bacteria and their germs would be unmeaning—but of this more anon.

'What present warrant,' it has been asked, 'is there for supposing that a naked, or almost naked, speck of protoplasm can withstand four, six, or eight hours' boiling?' Regarding naked specks of protoplasm I make no assertion. I know nothing about them, save as the creatures of fancy. But I do affirm, not as a 'supposition,' nor an 'assumption,' nor a 'probable guess,' nor as 'a wild hypothesis,' but as a matter of the most undoubted fact, that the spores of the hay bacillus, when thoroughly desiccated by age, have withstood the ordeal mentioned. And I further affirm that these obdurate germs, under the guidance of the knowledge that they *are* germs, can be destroyed by five minutes' boiling, or even less. This needs explanation. The finished bacterium perishes at a temperature far below that of boiling water, and it is fair to assume that the nearer the germ is to its final sensitive condition the more readily will it succumb to heat. Seeds soften before and during germination. This premised, the simple description of the following process will suffice to make its meaning understood.

An infusion infected with the most powerfully resistent germs, but otherwise protected against the floating matters of the air, is gradually raised to its boiling-point. Such germs as have reached the soft and plastic state immediately preceding their development into bacteria are thus destroyed. The infusion is then put aside in a warm room for ten or twelve hours. If for twenty-four, we might have the liquid charged with well-developed bacteria. To anticipate this, at the end of ten or twelve hours we raise the infusion a second time to the boiling temperature, which, as before, destroys all germs then approaching their point of final development. The infusion is again put aside for ten or twelve hours, and the process of heating is repeated. We thus kill the germs *in the order of their resistance*, and finally kill the last of them. No infusion can withstand this process if it be repeated a sufficient number of times. Artichoke, cucumber, and turnip infusions, which had proved specially obstinate when infected with the germs of desiccated hay, were completely broken down by this method of discontinuous heating, three minutes being found sufficient to accomplish what three hundred minutes' continuous boiling failed to accomplish. I applied the method, moreover, to infusions of various kinds of hay, including those most tenacious of life. Not one of them bore the ordeal. These results were clearly foreseen before they were realised, so that the germ theory fulfils the test of every true theory, that test being the power of prevision.

When 'naked or almost naked specks of protoplasm' are spoken of, the imagination is drawn upon, not the objective truth of Nature. Such words sound like the words of knowledge where knowledge is really *nil.* The possibility of a 'thin covering' is conceded by those who speak in this way. Such a covering may, however, exercise a powerful protective influence. A thin pellicle of india-rubber, for example, surrounding a pea keeps it hard in boiling water for a time sufficient to reduce an uncovered pea to a pulp. The pellicle prevents imbibition, diffusion, and the consequent disintegration. A greasy or oily surface, or even the layer of air which clings to certain bodies, would act to some extent in a similar way. 'The singular resistance of green vegetables to sterilisation,' says Dr. William Roberts, 'appears to be due to some peculiarity of the surface, perhaps their smooth glistening epidermis which prevented complete wetting of their surfaces.' I pointed out in 1876 that the process by which an atmospheric germ is wetted would be an interesting subject of investigation. A dry microscope covering-glass may be caused to float on water for a year. A sewing-needle may be similarly kept floating, though its specific gravity is nearly eight times that of water.

Were it not for some specific relation between the matter of the germ and that of the liquid into which it falls, wetting would be simply impossible. Antecedent to all development there must be an interchange of matter between the germ and its environment; and this interchange must obviously depend upon the relation of the germ to its encompassing liquid. Anything that hinders this interchange retards the destruction of the germ in boiling water. In my paper published in the 'Philosophical Transactions' for 1877, I add the following remark:—

> It is not difficult to see that the surface of a seed or germ may be so affected by desiccation and other causes as practically to prevent contact between it and the surrounding liquid. The body of a germ, moreover, may be so indurated by time and dryness as to resist powerfully the insinuation of water between its constituent molecules. It would be difficult to cause such a germ to imbibe the moisture necessary to produce the swelling and softening which precede its destruction in a liquid of high temperature.

However this may be—whatever be the state of the surface, or of the body, of the spores of *Bacillus subtilis*, they do as a matter of certainty resist, under some circumstances, exposure for hours to the heat of boiling water. No theoretic scepticism can successfully stand in the way of this fact, established as it has been by hundreds, if not thousands, of rigidly conducted experiments.

We have now to test one of the principal foundations of the doctrine of spontaneous generation as formulated in this country. With this view, I place before my friend and co-enquirer two liquids which have been kept for six months in one of our sealed chambers, exposed to optically pure air. The one is a mineral solution containing in proper proportions all the substances which enter into the composition of bacteria, the other is an infusion of turnip—it might be any one of a hundred other infusions, animal or vegetable. Both liquids are as clear as distilled water, and there is no trace of life in either of them. They are, in fact, completely sterilised. A mutton-chop, over which a little water has been poured to keep its juices from drying up, has lain for three days upon a plate in our warm room. It smells offensively. Placing a drop of the fetid mutton-juice under a microscope, it is found swarming with the bacteria of putrefaction. With a speck of the swarming liquid I inoculate the clear mineral solution and the clear turnip infusion, as a surgeon might inoculate an infant with vaccine lymph. In four-and-twenty hours the transparent liquids have become turbid throughout, and instead of being barren as at first they are teeming with life. The experiment may be repeated a thousand times with the same invariable result. To the naked eye the liquids at the beginning were alike, being both equally transparent—to the naked eye they are alike at the end, being both equally muddy. Instead of putrid mutton-juice, we might take as a source of infection any one of a hundred other putrid liquids, animal or vegetable. So long as the liquid contains living bacteria a speck of it communicated either to the clear mineral solution, or to the clear turnip infusion, produces in twenty-four hours the effect here described.

We now vary the experiment thus:—Opening the back-door of another closed chamber which has contained for months the pure mineral solution and the pure turnip infusion side by side, I drop into each of them a small pinch of laboratory dust. The effect here is tardier than when the speck of putrid liquid was employed. In three days, however, after its infection with the dust, the turnip infusion is muddy, and swarming as before with bacteria. But what about the mineral solution which, in our first experiment, behaved in a manner undistinguishable from the turnip-juice? At the end of three days there is not a bacterium to be found in it. At the end of three weeks it is equally innocent of bacterial life. We may repeat the experiment with the solution and the infusion a hundred times with the same invariable result. Always in the case of the latter the sowing of the atmospheric dust yields a crop of bacteria—never in the former does the dry germinal matter kindle into active life.[1] What is the inference which the reflecting mind must draw from this experiment? Is it not as clear as day that while both liquids are able to feed the bacteria and to enable them to increase and multiply, *after they have been once fully developed*, only one of the liquids is able to develope into active bacteria the germinal dust of the air?

I invite my friend to reflect upon this conclusion; he will, I think, see that there is no escape from it. He may, if he prefers, hold the opinion, which I consider erroneous, that bacteria exist in the air, not as germs but as desiccated organisms. The inference remains, that while the one liquid is able to force the passage from the inactive to the active state, the other is not.

But this is not at all the inference which has been drawn from experiments with the mineral solution.

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[1] This is the deportment of the mineral solution as described by others. My own experiments would lead me to say that the development of the bacteria, though exceedingly slow and difficult, is not impossible.

Seeing its ability to nourish bacteria when once inoculated with the living active organism, and observing that no bacteria appeared in the solution after long exposure to the air, the inference was drawn that *neither bacteria nor their germs existed in the air.* Throughout Germany the ablest literature of the subject, even that opposed to heterogeny, is infected with this error while heterogenists at home and abroad have based upon it a triumphant demonstration of their doctrine. It is proved, they say, by the deportment of the mineral solution that neither bacteria nor their germs exist in the air; hence, if, on exposing a thoroughly sterilised turnip infusion to the air, bacteria appear, they must of necessity have been spontaneously generated. In the words of Dr. Bastian: 'We can only infer that whilst the boiled saline solution is quite incapable of engendering bacteria, such organisms are able to arise *de novo* in the boiled organic infusion.'[1]

I would ask my eminent colleague what he thinks of this reasoning now? The *datum* is—'A mineral solution exposed to common air does not develope bacteria;' the *inference* is—'Therefore if a turnip infusion similarly exposed develope bacteria, they must be spontaneously generated.' The inference, on the face of it, is an unwarranted one. But while as matter of logic it is inconclusive, as matter of fact it is chimerical. London air is as surely charged with the germs of bacteria as London chimneys are with smoke. The inference just referred to is completely disposed of by the simple question: 'Why, when your sterilised organic infusion is exposed to optically pure air, should this generation of life *de novo* utterly cease? Why should I be able to preserve my turnip-juice side by side with your saline solution for the three hundred and sixty-five days of the year, in free connection with the general atmosphere, on the sole condition that the portion of that atmosphere in contact with the juice shall be visibly free from floating dust, while three days' exposure to that dust fills it with bacteria?' Am I over sanguine in hoping that as regards the argument here set forth he who runs may read, and he who reads may understand?

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[1] 'Proceedings of the Royal Society,' vol. xxi. p. 130.

We now proceed to the calm and thorough consideration of another subject, more important if possible than the foregoing one, but like it somewhat difficult to seize by reason of the very opulence of the phraseology, logical and rhetorical, in which it has been set forth. The subject now to be considered relates to what has been called 'the death-point of bacteria.' Those who happen to be acquainted with the modern English literature of the question will remember how challenge after challenge has been issued to panspermatists in general, and to one or two home workers in particular, to come to close quarters on this cardinal point. It is obviously the stronghold of the English heterogenist. 'Water,' he says, 'is boiling merrily over a fire when some luckless person upsets the vessel so that the heated fluid exercises its scathing influence upon an uncovered portion of the body—hand, arm, or face. Here, at all events, there is no room for doubt. Boiling water unquestionably exercises a most pernicious and rapidly destructive effect upon the living matter of which we are composed.'[1] And lest it should be supposed that it is the high organisation which, in this case, renders the body susceptible to heat, he refers to the action of boiling water on the hen's egg to dissipate the notion. 'The conclusion,' he says, 'would seem to force itself upon us that there is something intrinsically deleterious in the action of boiling water upon living matter—whether this matter be of high or of low organisation.'[1] Again, at another place: 'It has been shown that the briefest exposure to the influence of boiling water is destructive of all living matter.'[2]

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[1] Bastian, 'Evolution,' p. 133.

The experiments already recorded plainly show that there is a marked difference between the dry bacterial matter of the air, and the wet, soft, and active bacteria of putrefying organic liquids. The one can be luxuriantly bred in the saline solution, the others refuse to be born there, while both of them are copiously developed in a sterilised turnip infusion. Inferences, as we have already seen, founded on the deportment of the one liquid cannot with the warrant of scientific logic be extended to the other. But this is exactly what the heterogenist has done, thus repeating as regards the death-point of bacteria the error into which he fell concerning the germs of the air. Let us boil our muddy mineral solution with its swarming bacteria for five minutes. In the soft succulent condition in which they exist in the solution not one of them escapes destruction. The same is true of the turnip infusion if it be inoculated with the living bacteria only—the aërial dust being carefully excluded. In both cases the dead organisms sink to the bottom of the liquid, and without re-inoculation no fresh organisms will arise. But the case is entirely different when we inoculate our turnip infusion with the desiccated germinal matter afloat in the air.

The 'death-point' of bacteria is the maximum temperature at which they can live, or the minimum temperature at which they cease to live. If, for example they survive a temperature of 140°, and do not survive a temperature of 150°, the death-point lies somewhere between these two temperatures. Vaccine lymph, for example, is proved by Messrs. Braidwood and Vacher to be deprived of its power of infection by brief exposure to a temperature between 140° and 150° Fahr. This may be regarded as the death-point of the lymph, or rather of the particles diffused in the lymph, which constitute the real contagium. If no time, however, be named for the application of the heat, the term 'death-point' is a vague one. An infusion, for example, which will resist five hours' continuous exposure to the boiling temperature, will succumb to five days' exposure to a temperature 50° Fahr. below that of boiling. The fully developed soft bacteria of putrefying liquids are not only killed by five minutes' boiling, but by less than a single minute's boiling—indeed, they are slain at about the same temperature as the vaccine. The same is true of the plastic, active bacteria of the turnip infusion.[1]

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[1] Bastian, 'Evolution,' p. 135.

[2] *Ibid.* p. 46.

But, instead of choosing a putrefying liquid for inoculation, let us prepare and employ our inoculating substance in the following simple way:—Let a small wisp of hay, desiccated by age, be washed in a glass of water, and let a perfectly sterilised turnip infusion be inoculated with the washing liquid. After three hours' continuous boiling the infusion thus infected will often develope luxuriant bacterial life. Precisely the same occurs if a turnip infusion be prepared in an atmosphere well charged with desiccated hay-germs. The infusion in this case infects itself without special inoculation, and its subsequent resistance to sterilisation is often very great. On the 1st of March last I purposely infected the air of our laboratory with the germinal dust of a sapless kind of hay mown in 1875. Ten groups of flasks were charged with turnip infusion prepared in the infected laboratory, and were afterwards subjected to the boiling temperature for periods varying from 15 minutes to 240 minutes. Out of the ten groups only one was sterilised—that, namely, which had been boiled for four hours. Every flask of the nine groups which had been boiled for 15, 30, 45, 60, 75, 90, 105, 120, and 180 minutes respectively, bred organisms afterwards. The same is true of other vegetable infusions. On the 28th of February last, for example, I boiled six flasks, containing cucumber infusion prepared in an infected atmosphere, for periods of 15, 30, 45, 60, 120, and 180 minutes. Every flask of the group subsequently developed organisms. On the same day, in the case of three flasks, the boiling was prolonged to 240, 300, and 360 minutes; and these three flasks were completely sterilised. Animal infusions, which under ordinary circumstances are rendered infallibly barren by five minutes' boiling, behave like the vegetable infusions in an atmosphere infected with hay-germs. On the 30th of March, for example, five flasks were charged with a clear infusion of beef and boiled for 60 minutes, 120 minutes, 180 minutes, 240 minutes, and 300 minutes respectively. Every one of them became subsequently crowded with organisms, and the same happened to a perfectly pellucid mutton infusion prepared at the same time. The cases are to be numbered by hundreds in which similar powers of resistance were manifested by infusions of the most diverse kinds.

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[1] In my paper in the 'Philosophical Transactions' for 1876, I pointed out and illustrated experimentally the difference, as regards rapidity of development, between water-germs and air-germs; the growth from the already softened water-germs proving to be practically as rapid as from developed bacteria. This preparedness of the germ for rapid development is associated with its preparedness for rapid destruction.

In the presence of such facts I would ask my colleague whether it is necessary to dwell for a single instant on the one-sidedness of the evidence which led to the conclusion that all living matter has its life destroyed by 'the briefest exposure to the influence of boiling water.' An infusion proved to be barren by six months' exposure to moteless air maintained at a temperature of 90° Fahr., when inoculated with full-grown active bacteria, fills itself in two days with organisms so sensitive as to be killed by a few minutes' exposure to a temperature much below that of boiling water. But the extension of this result to the desiccated germinal matter of the air is without warrant or justification. This is obvious without going beyond the argument itself. But we have gone far beyond the argument, and proved by multiplied experiment the alleged destruction of all living matter by the briefest exposure to the influence of boiling water to be a delusion. The whole logical edifice raised upon this basis falls therefore to the ground; and the argument that bacteria and their germs, being destroyed at 140°, must, if they appear after exposure to 212°, be spontaneously generated, is, I trust, silenced for ever.

Through the precautions, variations, and repetitions observed and executed with the view of rendering its results secure, the separate vessels employed in this enquiry have mounted up in two years to nearly ten thousand.

Besides the philosophic interest attaching to the problem of life's origin, which will be always immense, there are the practical interests involved in the application of the doctrines here discussed to surgery and medicine. The antiseptic system, at which I have already glanced, illustrates the manner in which beneficent results of the gravest moment follow in the wake of clear theoretic insight. Surgery was once a noble art; it is now, as well, a noble science. Prior to the introduction of the antiseptic system, the thoughtful surgeon could not have failed to learn empirically that there was something in the air which often defeated the most consummate operative skill. That something the antiseptic treatment destroys or renders innocuous. At King's College Mr. Lister operates and dresses while a fine shower of mixed carbolic acid and water, produced in the simplest manner, falls upon the wound, the lint and gauze employed in the subsequent dressing being duly saturated with the antiseptic. At St. Bartholomew's Mr. Callender employs the dilute carbolic acid without the spray; but, as regards the real point aimed at—the preventing of the wound from becoming a nidus for the propagation of septic bacteria—the practice in both hospitals is the same. Commending itself as it does to the scientifically trained mind, the antiseptic system has struck deep root in Germany.

Had space allowed, it would have given me pleasure to point out the present position of the 'germ theory' in reference to the phenomena of infectious disease, distinguishing arguments based on analogy—which, however, are terribly strong—from those based on actual observation. I should have liked to follow up the account I have already given[1] of the truly excellent researches of a young and an unknown German physician named Koch, on splenic fever, by an account of what Pasteur has recently done with reference to the same subject. Here we have before us a living contagium of the most deadly power, which we can follow from the beginning to the end of its life cycle.[2] We find it in the blood or spleen of a smitten animal in the state say of short motionless rods. When these rods are placed in a nutritive liquid on the warm stage of the microscope, we soon see them lengthening into filaments which lie, in some cases, side by side, forming in others graceful loops, or becoming coiled into knots of a complexity not to be unravelled. We finally see those filaments resolving themselves into innumerable spores, each with death potentially housed within it, yet not to be distinguished microscopically from the harmless germs of *Bacillus subtilis.* The bacterium of splenic fever is called *Bacillus Anthracis.* This formidable organism was shown to me by M. Pasteur in Paris last July. His recent investigations regarding the part it plays pathologically certainly rank amongst the most remarkable labours of that remarkable man. Observer after observer had strayed and fallen in this land of pitfalls, a multitude of opposing conclusions and mutually destructive theories being the result. In association with a younger physiological colleague, M. Joubert, Pasteur struck in amidst the chaos, and soon reduced it to harmony. They proved, among other things, that in cases where previous observers in France had supposed themselves to be dealing solely with splenic fever, another equally virulent factor was simultaneously active. Splenic fever was often overmastered by septicæmia, and results due solely to the latter had been frequently made the ground of pathological inferences regarding the character and cause of the former. Combining duly the two factors, all the previous irregularities disappeared, every result obtained receiving the fullest explanation. On studying the account of this masterly investigation, the words wherewith Pasteur himself feelingly alludes to the difficulties and dangers of the experimenter's art came home to

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[1] 'Fortnightly Review,' November 1876, see article 'Fermentation.'

[2] Dallinger and Drysdale had previously shown what skill and patience can accomplish, by their admirable observations on the life history of the monads.

me with especial force: 'J'ai tant de fois éprouvé que dans cet art difficile de l'expérimentation les plus habiles bronchent à chaque pas, et que l'interprétation des faits n'est pas moins périlleuse.'[1]

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[1] 'Comptes-Rendus,' lxxxiii. p. 177.

XIV.

SCIENCE AND MAN.[1]

A MAGNET attracts iron; but when we analyse the effect we learn that the metal is not only attracted but repelled, the final approach to the magnet being due to the difference of two unequal and opposing forces. Social progress is for the most part typified by this duplex or polar action. As a general rule, every advance is balanced by a partial retreat, every amelioration is associated more or less with deterioration. No great mechanical improvement, for example, is introduced for the benefit of society at large that does not bear hardly upon individuals. Science, like other things, is subject to the operation of this polar law, what is good for it under one aspect being bad for it under another.

Science demands above all things personal concentration. Its home is the study of the mathematician, the quiet laboratory of the experimenter, and the cabinet of the meditative observer of nature. Different atmospheres are required by the man of science, as such, and the man of action. Thus the facilities of social and international intercourse, the railway, the telegraph, and the post-office, which are such undoubted boons to the man of action, react to some extent injuriously on the man of science. Their tendency is to break up that concentrativeness which, as I have said, is an absolute necessity to the scientific investigator.

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[1] Presidential Address, delivered before the Birmingham and Midland Institute, October 1, 1877; with additions.

The men who have most profoundly influenced the world from the scientific side have habitually sought isolation. Faraday, at a certain period of his career, formally renounced dining out. Darwin lives apart from the bustle of the world in his quiet home in Kent. Mayer and Joule dealt in unobtrusive retirement with the weightiest scientific questions. There is, however, one motive power in the world which no man, be he a scientific student or otherwise, can afford to treat with indifference; and that is, the cultivation of right relations with his fellow-men—the performance of his duty, not as an isolated individual, but as a member of society. It is duty in this aspect, overcoming alike the sense of possible danger and the desire for repose, that has placed me in your presence here to-night.

To look at his picture as a whole, a painter requires distance; and to judge of the total scientific achievement of any age, the standpoint of a succeeding age is desirable. We may, however, transport ourselves in idea into the future, and thus survey with more or less completeness the science of our time. We sometimes hear it decried, and contrasted to its disadvantage with the science of other times. I do not think that this will be the verdict of posterity. I think, on the contrary, that posterity will acknowledge that in the history of science no higher samples of intellectual conquest are recorded than those which this age has made its own. One of the most salient of these I propose, with your permission, to make the subject of our consideration during the coming hour.

It is now generally admitted that the man of to-day is the child and product of incalculable antecedent time. His physical and intellectual textures have been woven for him during his passage through phases of history and forms of existence which lead the mind back to an abysmal past. One of the qualities which he has derived from that past is the yearning to let in the light of principles on the otherwise bewildering flux of phenomena. He has been described by the German Lichtenberg as 'das rastlose Ursachenthier'—the restless cause-seeking animal—in whom facts excite a kind of hunger to know the sources from which they spring. Never, I venture to say, in the history of the world has this longing been more liberally responded to, both among men of science and the general public, than during the last thirty or forty years. I say 'the general public,' because it is a feature of our time that the man of science no longer limits his labours to the society of his colleagues and his peers, but shares, as far as it is possible to share, with the world at large the fruits of enquiry.

The celebrated Robert Boyle regarded the universe as a machine; Mr. Carlyle prefers regarding it as a tree. He loves the image of the umbrageous Igdrasil better than that of the Strasburg clock. A machine may be defined as an organism with life and direction outside; a tree may be defined as an organism with life and direction within. In the light of these definitions, I close with the conception of Carlyle. The order and energy of the universe I hold to be inherent, and not imposed from without, the expression of fixed law and not of arbitrary will, exercised by what Carlyle would call an Almighty Clockmaker. But the two conceptions are not so much opposed to each other after all. In one fundamental particular they at all events agree. They equally imply the interdependence and harmonious interaction of parts, and the subordination of the individual powers of the universal organism to the working of the whole.

Never were the harmony and interdependence just referred to so clearly recognised as now. Our insight regarding them is not that vague and general insight to which our fathers had attained, and which, in early times, was more frequently affirmed by the synthetic poet than by the scientific man. The interdependence of our day has become quantitative—expressible by numbers—leading, it must be added, directly into that inexorable reign of law which so many gentle people regard with dread. In the domain now under review men of science had first to work their way from darkness into twilight, and from twilight into day. There is no solution of continuity in science. It is not given to any man, however endowed, to rise spontaneously into intellectual splendour without the parentage of antecedent thought. Great discoveries grow. Here, as in other cases, we have first the seed, then the ear, then the full corn in the ear, the last member of the series implying the first. Thus, as regards the discovery of gravitation with which the name of Newton is identified, notions more or less clear concerning it had entered many minds before Newton's transcendent mathematical genius raised it to the level of a demonstration. The whole of his deductions, moreover, rested upon the inductions of Kepler. Newton shot beyond his predecessors; but his thoughts were rooted in their thoughts, and a just distribution of merit would assign to them a fair portion of the honour of discovery.

Scientific theories sometimes float like rumours in the air before they receive complete expression. The doom of a doctrine is often practically sealed, and the truth of one is often practically accepted, long prior to the demonstration of either the error or the truth.

Perpetual motion was discarded before it was proved to be opposed to natural law; and, as regards the connection and interaction of natural forces, intimations of modern discoveries are strewn through the writings of Leibnitz, Boyle, Hooke, Locke and others.

Confining ourselves to recent times, Dr. Ingleby has pointed out to me some singularly sagacious remarks bearing upon this question, which were published by an anonymous writer in 1820. Roget's penetration was conspicuous in 1829. Mohr had grasped in 1837 some deep-lying truth. The writings of Faraday furnish frequent illustrations of his profound belief in the unity of nature. 'I have long,' he writes in 1845, 'held an opinion almost amounting to conviction, in common, I believe, with other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin, or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, one into another, and possess equivalence of power in their action.' His own researches on magneto-electricity, on electro-chemistry, and on the 'magnetisation of light,' led him directly to this belief. At an early date Mr. Justice Grove made his mark upon this question. Colding, though starting from a metaphysical basis, grasped eventually the relation between heat and mechanical work, and sought to determine it experimentally. And here let me say, that to him who has only the truth at heart, and who in his dealings with scientific history keeps his soul unwarped by envy, hatred, or malice, personal or national, every fresh accession to historic knowledge must be welcome. For every new-comer of proved merit, more especially if that merit should have been previously overlooked, he makes ready room in his recognition or his reverence. But no retrospect of scientific literature has as yet brought to light a claim which can sensibly affect the positions accorded to two great *Path-hewers*, as the Germans call them, whose names in relation to this subject are linked in indissoluble association. These names are Julius Robert Mayer and James Prescott Joule.

In his essay on 'Circles' Mr. Emerson, if I remember rightly, pictured intellectual progress as rhythmic. At a given moment knowledge is surrounded by a barrier which marks its limit. It gradually gathers clearness and strength until by-and-by some thinker of exceptional power bursts the barrier and wins a wider circle, within which thought once more entrenches itself. But the internal force again accumulates, the new barrier is in its turn broken, and the mind finds itself surrounded by a still wider horizon. Thus, according to Emerson, knowledge spreads by intermittent victories instead of progressing at a uniform rate.

When Dr. Joule first proved that a weight of one pound, falling through a height of seven hundred and seventy-two feet, generated an amount of heat competent to warm a pound of water one degree Fahrenheit, and that in lifting the weight so much heat exactly disappeared, he broke an Emersonian 'circle,' releasing by the act an amount of scientific energy which rapidly overran a vast domain, and embodied itself in the great doctrine known as the 'Conservation of Energy.' This doctrine recognises in the material universe a constant sum of power made up of items among which the most Protean fluctuations are incessantly going on. It is as if the body of Nature were alive, the thrill and interchange of its energies resembling those of an organism. The parts of the 'stupendous whole' shift and change, augment and diminish, appear and disappear, while the total of which they are the parts remains quantitatively immutable. Immutable, because when change occurs it is always polar—plus accompanies minus, gain accompanies loss, no item varying in the slightest degree without an absolutely equal change of some other item in the opposite direction.

The sun warms the tropical ocean, converting a portion of its liquid into vapour, which rises in the air and is recondensed on mountain heights, returning in rivers to the ocean from which it came. Up to the point where condensation begins, an amount of heat exactly equivalent to the molecular work of vaporisation and the mechanical work of lifting the vapour to the mountain-tops has disappeared from the universe. What is the gain corresponding to this loss? It will seem when mentioned to be expressed in a foreign currency. The loss is a loss of heat; the gain is a gain of distance, both as regards masses and molecules. Water which was formerly at the sea-level has been lifted to a position from which it can fall; molecules which have been locked together as a liquid are now separate as vapour which can recondense. After condensation gravity comes into effectual play, pulling the showers down upon the hills, and the rivers thus created through their gorges to the sea. Every raindrop which smites the mountain produces its definite amount of heat; every river in its course develops heat by the clash of its cataracts and the friction of its bed. In the act of condensation, moreover, the molecular work of vaporisation is accurately reversed. Compare, then, the primitive loss of solar warmth with the heat generated by the condensation of the vapour, and by the subsequent fall of the water from cloud to sea. They are mathematically equal to each other. No particle of vapour was formed and lifted without being paid for in the currency of solar heat; no particle returns as water to the sea without the exact quantitative restitution of that heat. There is nothing gratuitous in physical nature, no expenditure without equivalent gain, no gain without equivalent expenditure. With inexorable constancy the one accompanies the other, leaving no nook or crevice between them for spontaneity to mingle with the pure and necessary play of natural force. Has this uniformity of nature ever been broken? The reply is: 'Not to the knowledge of science.'

What has been here stated regarding heat and gravity applies to the whole of inorganic nature. Let us take an illustration from chemistry. The metal zinc may be burnt in oxygen, a perfectly definite amount of heat being produced by the combustion of a given weight of the metal. But zinc may also be burnt in a liquid which contains a supply of oxygen—in water, for example. It does not in this case produce flame or fire, but it does produce heat which is capable of accurate measurement. But the heat of zinc burnt in water falls short of that produced in pure oxygen, the reason being that to obtain its oxygen from the water the zinc must first dislodge the hydrogen. It is in the performance of this molecular work that the missing heat is absorbed. Mix the liberated hydrogen with oxygen and cause them to recombine; the heat developed is mathematically equal to the missing heat. Thus in pulling the oxygen and hydrogen asunder an amount of heat is consumed which is accurately restored by their reunion.

This leads up to a few remarks upon the Voltaic battery. It is not my design to dwell upon the technical features of this wonderful instrument, but simply, by means of it, to show what varying shapes a given amount of energy can assume while maintaining unvarying quantitative stability. When that form of power which we call an electric current passes through Grove's battery, zinc is consumed in acidulated water; and in the battery we are able so to arrange matters that when no current passes no zinc shall be consumed. Now the current, whatever it may be, possesses the power of generating heat outside the battery. We can fuse with it iridium, the most refractory of metals, or we can produce with it the dazzling electric light, and that at any terrestrial distance from the battery itself.

We will now, however, content ourselves with causing the current to raise a given length of platinum wire, first to a blood-heat, then to redness, and finally to a white heat. The heat under these circumstances generated in the battery by the combustion of a fixed quantity of zinc is no longer constant, but it varies inversely as the heat generated outside. If the outside heat be *nil*, the inside heat is a maximum; if the external wire be raised to a blood-heat, the internal heat falls slightly short of the maximum. If the wire be rendered red-hot, the quantity of missing heat within the battery is greater, and if the external wire be rendered white-hot, the defect is greater still. Add together the internal and external heat produced by the combustion of a given weight of zinc, and you have an absolutely constant total. The heat generated without is so much lost within, the heat generated within is so much lost without, the polar changes already adverted to coming here conspicuously into play. Thus in a variety of ways we can distribute the items of a never-varying sum, but even the subtle agency of the electric current places no creative power in our hands.

Instead of generating external heat, we may cause the current to effect chemical decomposition at a distance from the battery. Let it, for example, decompose water into oxygen and hydrogen. The heat generated in the battery under these circumstances by the combustion of a given weight of zinc falls short of what is produced when there is no decomposition. How far short? The question admits of a perfectly exact answer. When the oxygen and hydrogen recombine, the heat absorbed in the decomposition is accurately restored, and it is exactly equal in amount to that missing in the battery. We may, if we like, bottle up the gases, carry in this form the heat of the battery to the polar regions, and liberate it there. The battery, in fact, is a hearth on which fuel is consumed; but the heat of the combustion, instead of being confined in the usual manner to the hearth itself, may be first liberated at the other side of the world.

And here we are able to solve an enigma which long perplexed scientific men, and which could not be solved until the bearing of the mechanical theory of heat upon the phenomena of the Voltaic battery was understood. The puzzle was, that a single cell could not decompose water. The reason is now plain enough. The solution of an equivalent of zinc in a single cell develops not much more than half the amount of heat required to decompose an equivalent of water, and the single cell cannot cede an amount of force which it does not possess. But by forming a battery of two cells instead of one, we develop an amount of heat slightly in excess of that needed for the decomposition of the water. The two-celled battery is therefore rich enough to pay for that decomposition, and to maintain the excess referred to within its own cells.

Similar reflections apply to the thermo-electric pile, an instrument usually composed of small bars of bismuth and antimony soldered alternately together. The electric current is here evoked by warming the soldered junctions of one face of the pile. Like the Voltaic current, the thermo-electric current can heat wires, produce decomposition, magnetise iron, and deflect a magnetic needle at any distance from its origin. You will be disposed, and rightly disposed, to refer those distant manifestations of power to the heat communicated to the face of the pile, but the case is worthy of closer examination. In 1826 Thomas Seebeck discovered thermo-electricity, and six years subsequently Peltier made an observation which comes with singular felicity to our aid in determining the material used up in the formation of the thermo-electric current. He found that when a weak extraneous current was sent from antimony to bismuth the junction of the two metals was always heated, but that when the direction was from bismuth to antimony the junction was chilled. Now the current in the thermo-pile itself is always from bismuth to antimony, across the heated junction—a direction in which it cannot possibly establish itself without consuming the heat imparted to the junction. This heat is the nutriment of the current. Thus the heat generated by the thermo-current in a distant wire is simply that originally imparted to the pile, which has been first transmuted into electricity, and then retransmuted into its first form at a distance from its origin. As water in a state of vapour passes from a boiler to a distant condenser, and there assumes its primitive form without gain or loss, so the heat communicated to the thermo-pile distils into the subtler electric current, which is, as it were, recondensed into heat in the distant platinum wire.

In my youth I thought an electro-magnetic engine which was shown to me a veritable perpetual motion—a machine, that is to say, which performed work without the expenditure of power. Let us consider the action of such a machine. Suppose it to be employed to pump water from a lower to a higher level. On examining the battery which works the engine we find that the zinc consumed does not yield its full amount of heat. The quantity of heat thus missing within is the exact thermal equivalent of the mechanical work performed without. Let the water fall again to the lower level; it is warmed by the fall. Add the heat thus produced to that generated by the friction, mechanical and magnetical, of the engine; we thus obtain the precise amount of heat missing in the battery. All the effects obtained from the machine are thus strictly paid for; this 'payment for results' being, I would repeat, the inexorable method of nature.

No engine, however subtly devised, can evade this law of equivalence, or perform on its own account the smallest modicum of work. The machine distributes, but it cannot create. Is the animal body, then, to be classed among machines? When I lift a weight, or throw a stone, or climb a mountain, or wrestle with my comrade, am I not conscious of actually creating and expending force? Let us look at the antecedents of this force. We derive the muscle and fat of our bodies from what we eat. Animal heat you know to be due to the slow combustion of this fuel. My arm is now inactive, and the ordinary slow combustion of my blood and tissue is going on. For every grain of fuel thus burnt a perfectly definite amount of heat has been produced. I now contract my biceps muscle without causing it to perform external work. The combustion is quickened, and the heat is increased; this additional heat being liberated in the muscle itself. I lay hold of a 56 lb. weight, and by the contraction of my biceps lift it through the vertical space of a foot. The blood and tissue consumed during this contraction have not developed in the muscle their due amount of heat. A quantity of heat is at this moment missing in my muscle which would raise the temperature of an ounce of water somewhat more than one degree Fahrenheit. I liberate the weight: it falls to the earth, and by its collision generates the precise amount of heat missing in the muscle. My muscular heat is thus transferred from its local hearth to external space. The fuel is consumed in my body, but the heat of combustion is produced outside my body. The case is substantially the same as that of the Voltaic battery when it performs external work, or produces external heat. All this points to the conclusion that the force we employ in muscular exertion is the force of burning fuel and not of creative will. In the light of these facts the body is seen to be as incapable of generating energy without expenditure, as the solids and liquids of the Voltaic battery. The body, in other words, falls into the category of machines.

We can do with the body all that we have already done with the battery—heat platinum wires, decompose water, magnetise iron, and deflect a magnetic needle. The combustion of muscle may be made to produce all these effects, as the combustion of zinc may be caused to produce them. By turning the handle of a magneto-electric machine a coil of wire may be caused to rotate between the poles of a magnet. As long as the two ends of the coil are unconnected we have simply to overcome the ordinary inertia and friction of the machine in turning the handle. But the moment the two ends of the coil are united by a thin platinum wire a sudden addition of labour is thrown upon the turning arm. When the necessary labour is expended, its equivalent immediately appears. The platinum wire glows. You can readily maintain it at a white heat, or even fuse it. This is a very remarkable result. From the muscles of the arm, with a temperature of 100°, we extract the temperature of molten platinum, which is nearly four thousand degrees. The miracle here is the reverse of that of the burning bush mentioned in Exodus. There the bush burned, but was not consumed: here the body is consumed, but does not burn. The similarity of the action with that of the Voltaic battery when it heats an external wire is too obvious to need pointing out. When the machine is used to decompose water, the heat of the muscle, like that of the battery, is consumed in molecular work, being fully restored when the gases recombine. As before, also, the transmuted heat of the muscles may be bottled up, carried to the polar regions, and there restored to its pristine form.

The matter of the human body is the same as that of the world around us; and here we find the forces of the human body identical with those of inorganic nature. Just as little as the Voltaic battery is the animal body a creator of force. It is an apparatus exquisite and effectual beyond all others in transforming and distributing the energy with which it is supplied, but it possesses no creative power. Compared with the notions previously entertained regarding the play of 'vital force' this is a great result. The problem of vital dynamics has been described by a competent authority as 'the grandest of all.' I subscribe to this opinion, and honour correspondingly the man who first successfully grappled with the problem. He was no pope, in the sense of being infallible, but he was a man of genius whose work will be held in honour as long as science endures. I have already named him in connection with our illustrious countryman Dr. Joule. Other eminent men took up this subject subsequently and independently, but all that has been done hitherto enhances instead of diminishing the merits of Dr. Mayer.

Consider the vigour of his reasoning. 'Beyond the power of generating internal heat, the animal organism can generate heat external to itself. A blacksmith by hammering can warm a nail, and a savage by friction can heat wood to its point of ignition. Unless, then, we abandon the physiological axiom that the animal body cannot create heat out of nothing, we are driven to the conclusion that *it is the total heat, within and without, that ought to be regarded as the real calorific effect of the oxidation within the body*.' Mayer, however, not only states the principle, but illustrates numerically the transfer of muscular heat to external space. A bowler who imparts a velocity of 30 feet to an 8-lb. ball consumes in the act $\frac{1}{10}$ of a grain of carbon. The heat of the muscle is here distributed over the track of the ball, being developed there by mechanical friction. A man weighing 150 lbs. consumes in lifting his own body to a height of 8 feet the heat of a grain of carbon. Jumping from this height the heat is restored. The consumption of 2 oz. 4 drs. 20 grs. of carbon would place the same man on the summit of a mountain 10,000 feet high. In descending the mountain an amount of heat equal to that produced by the combustion of the foregoing amount of carbon is restored. The muscles of a labourer whose weight is 150 lbs. weigh 64 lbs. When dried they are reduced to 15 lbs. Were the oxidation corresponding to a day-labourer's ordinary work exerted on the muscles alone, they would be wholly consumed in 80 days. Were the oxidation necessary to sustain the heart's action concentrated on the heart itself, it would be consumed in 8 days. And if we confine our attention to the two ventricles, their action would consume the associated muscular tissue in 3½ days. With a fulness and precision of which this is but a sample did Mayer, between 1842 and 1845, deal with the great question of vital dynamics.

In direct opposition, moreover, to the foremost scientific authorities of that day, with Liebig at their head, this solitary Heilbronn worker was led by his calculations to maintain that the muscles, in the main, played the part of machinery, converting the fat, which had been previously considered a mere heat-producer, into the motive power of the organism. Mayer's prevision has been justified by events, for the scientific world is now upon his side.

We place, then, food in our stomachs as so much combustible matter. It is first dissolved by purely chemical processes, and the nutritive fluid is poured into the blood. Here it comes into contact with atmospheric oxygen admitted by the lungs. It unites with the oxygen as wood or coal might unite with it in a furnace. The matter-products of the union, if I may use the term, are the same in both cases, viz. carbonic acid and water. The force-products are also the same—heat within the body, or heat and work outside the body. Thus far every action of the organism belongs to the domain either of physics or of chemistry. But you saw me contract the muscle of my arm. What enabled me to do so? Was it or was it not the direct action of my will? The answer is, the action of the will is mediate, not direct. Over and above the muscles the human organism is provided with long whitish filaments of medullary matter, which issue from the spinal column, being connected by it on the one side with the brain, and on the other side losing themselves in the muscles. Those filaments or cords are the nerves, which you know are divided into two kinds, sensor and motor, or, if you like the terms better, afferent and efferent nerves. The former carry impressions from the external world to the brain; the latter convey the behests of the brain to the muscles. Here, as elsewhere, we find ourselves aided by the sagacity of Mayer, who was the first clearly to formulate the part played by the nerves in the organism. Mayer saw that neither nerves nor brain, nor both together, possessed the energy necessary to animal motion; but he also saw that the nerve could lift a latch and open a door, by which floods of energy are let loose. 'As an engineer,' he says with admirable lucidity, 'by the motion of his finger in opening a valve or loosening a detent can liberate an amount of mechanical energy almost infinite compared with its exciting cause; so the nerves, acting on the muscles, can unlock an amount of power out of all proportion to the work done by the nerves themselves.' The nerves, according to Mayer, pull the trigger, but the gunpowder which they ignite is stored in the muscles. This is the view now universally entertained.

The quickness of thought has passed into a proverb, and the notion that any measurable time elapsed between the infliction of a wound and the feeling of the injury would have been rejected as preposterous thirty years ago. Nervous impressions, notwithstanding the results of Haller, were thought to be transmitted, if not instantaneously, at all events with the rapidity of electricity. Hence, when Helmholtz, in 1851, affirmed, as the result of experiment, nervous transmission to be a comparatively sluggish process, very few believed him. His experiments may now be made in the lecture-room.

Sound in air moves at the rate of 1,100 feet a second; sound in water moves at the rate of 5,000 feet a second; light in ether moves at the rate of 186,000 miles a second, and electricity in free wires moves probably at the same rate. But the nerves transmit their messages at the rate of only 70 feet a second, a progress which in these quick times might well be regarded as inordinately slow.

Your townsman, Mr. Gore, has produced by electrolysis a kind of antimony which exhibits an action strikingly analogous to that of nervous propagation. A rod of this antimony is in such a molecular condition that when you scratch or heat one end of the rod, the disturbance propagates itself before your eyes to the other end, the onward march of the disturbance being announced by the development of heat and fumes along the line of propagation. In some such way the molecules of the nerves are successively overthrown; and if Mr. Gore could only devise some means of winding up his exhausted antimony, as the nutritive blood winds up exhausted nerves, the comparison would be complete. The subject may be summed up, as Du Bois-Reymond has summed it up, by reference to the case of a whale struck by a harpoon in the tail. If the animal were 70 feet long, a second would elapse before the disturbance could reach the brain. But the impression after its arrival has to diffuse itself and throw the brain into the molecular condition necessary to consciousness. Then, and not till then, the command to the tail to defend itself is shot through the motor nerves. Another second must elapse before the command can reach the tail, so that more than two seconds transpire between the infliction of the wound and the muscular response of the part wounded. The interval required for the kindling of consciousness would probably more than suffice for the destruction of the brain by lightning, or even by a rifle-bullet. Before the organ can arrange itself it may, therefore, be destroyed, and in such a case we may safely conclude that death is painless.

The experiences of common life supply us with copious instances of the liberation of vast stores of muscular power by an infinitesimal 'priming' of the muscles by the nerves. We all know the effect produced on a 'nervous' organisation by a slight sound which causes affright. An aërial wave, the energy of which would not reach a minute fraction of that necessary to raise the thousandth of a grain through the thousandth of an inch, can throw the whole human frame into a powerful mechanical spasm, followed by violent respiration and palpitation. The eye, of course, may be appealed to as well as the ear. Of this the lamented Lange gives the following vivid illustration:

A merchant sits complacently in his easy chair, not knowing whether smoking, sleeping, newspaper reading, or the digestion of food occupies the largest portion of his personality. A servant enters the room with a telegram bearing the words, 'Antwerp, &c. . . . Jonas and Co. have failed.' 'Tell James to harness the horses!' The servant flies. Up starts the merchant, wide awake; makes a dozen paces through the room, descends to the counting-house, dictates letters, and forwards despatches. He jumps into his carriage, the horses snort, and their driver is immediately at the Bank, on the Bourse, and among his commercial friends. Before an hour has elapsed he is again at home, where he throws himself once more into his easy chair with a deep-drawn sigh, 'Thank God I am protected against the worst, and now for further reflection.'

This complex mass of action, emotional, intellectual, and mechanical, is evoked by the impact upon the retina of the infinitesimal waves of light coming from a few pencil marks on a bit of paper. We have, as Lange says, terror, hope, sensation, calculation, possible ruin, and victory compressed into a moment. What caused the merchant to spring out of his chair? The contraction of his muscles. What made his muscles contract? An impulse of the nerves, which lifted the proper latch, and liberated the muscular power. Whence this impulse? From the centre of the nervous system. But how did it originate there? This is the critical question, to which some will reply that it had its origin in the human soul.

The aim and effort of science is to explain the unknown in terms of the known. Explanation, therefore, is conditioned by knowledge. You have probably heard the story of the German peasant, who, in early railway days, was taken to see the performance of a locomotive. He had never known carriages to be moved except by animal power. Every explanation outside of this conception lay beyond his experience, and could not be invoked. After long reflection therefore, and seeing no possible escape from the conclusion, he exclaimed confidently to his companion, 'Es müssen doch Pferde darin sein'—There must be horses inside. Amusing as this locomotive theory may seem, it illustrates a deep-lying truth.

With reference to our present question, some may be disposed to press upon me such considerations as these:—Your motor nerves are so many speaking-tubes, through which messages are sent from the man to the world; and your sensor nerves are so many conduits through which the whispers of the world are sent back to the man. But you have not told us where *is* the man. Who or what is it that sends and receives those messages through the bodily organism? Do not the phenomena point to the existence of a self within the self, which acts through the body as through a skilfully constructed instrument? You picture the muscles as hearkening to the commands sent through the motor nerves, and you picture the sensor nerves as the vehicles of incoming intelligence; are you not bound to supplement this mechanism by the assumption of an entity which uses it? In other words, are you not forced by your own exposition into the hypothesis of a free human soul?

This is fair reasoning now, and at a certain stage of the world's knowledge, it might well have been deemed conclusive. Adequate reflection, however, shows that instead of introducing light into our minds, this hypothesis considered scientifically increases our darkness. You do not in this case explain the unknown in terms of the known, which, as stated above, is the method of science, but you explain the unknown in terms of the more unknown. Try to mentally visualise this soul as an entity distinct from the body, and the difficulty immediately appears. From the side of science all that we are warranted in stating is that the terror, hope, sensation, and calculation of Lange's merchant, are psychical phenomena produced by, or associated with, the molecular processes set up by waves of light in a previously prepared brain.

When facts present themselves let us dare to face them, but let the man of science equally dare to confess ignorance where it prevails. What then is the causal connection, if any, between the objective and subjective—between molecular motions and states of consciousness? My answer is: I do not see the connection, nor have I as yet met anybody who does.

It is no explanation to say that the objective and subjective effects are two sides of one and the same phenomenon. Why should the phenomenon have two sides? This is the very core of the difficulty. There are plenty of molecular motions which do not exhibit this two-sidedness. Does water think or feel when it runs into frost-ferns upon a window-pane? If not, why should the molecular motion of the brain be yoked to this mysterious companion—consciousness? We can form a coherent picture of the physical processes—the stirring of the brain, the thrilling of the nerves, the discharging of the muscles, and all the subsequent mechanical motions of the organism. But we can present to our minds no picture of the process whereby consciousness emerges, either as a necessary link or as an accidental by-product of this series of actions. Yet it certainly does emerge—the prick of a pin suffices to prove that molecular motion can produce consciousness. The reverse process of the production of motion by consciousness is equally unpresentable to the mind. We are here, in fact, upon the boundary line of the intellect, where the ordinary canons of science fail to extricate us from our difficulties. If we are true to these canons, we must deny to subjective phenomena all influence on physical processes. Observation proves that they interact, but in passing from one to the other, we meet a blank which mechanical deduction is unable to fill. Frankly stated, we have here to deal with facts almost as difficult to seize mentally as the idea of a soul. And if you are content to make your 'soul' a poetic rendering of a phenomenon which refuses the yoke of ordinary physical laws, I, for one, would not object to this exercise of ideality. Amid all our speculative uncertainty, however, there is one practical point as clear as the day; namely, that the brightness and the usefulness of life, as well as its darkness and disaster, depend to a great extent upon our own use or abuse of this miraculous organ.

Accustomed as I am to harsh language, I am quite prepared to hear my 'poetic rendering' branded as a 'falsehood' and a 'fib.' The vituperation is unmerited, for poetry or ideality, and untruth are assuredly very different things. The one may vivify, while the other kills. When St. John extends the notion of a soul to 'souls washed in the blood of Christ' does he 'fib'? Indeed, if the appeal to ideality is censurable, Christ himself ought not to have escaped censure. Nor did he escape it. 'How can this man give us his flesh to eat?' expressed the sceptical flouting of unpoetic natures. Such are still amongst us. Cardinal Manning would doubtless tell any Protestant who rejects the doctrine of transubstantiation that he 'fibs' away the plain words of his Saviour when he reduces 'the Body of the Lord' in the sacrament to a mere figure of speech.

Though misuse may render it grotesque or insincere, the idealisation of ancient conceptions, when done consciously and above board, has, in my opinion, an important future. We are not radically different from our historic ancestors, and any feeling which affected them profoundly, requires only appropriate clothing to affect us. The world will not lightly relinquish its heritage of poetic feeling, and metaphysic will be welcomed when it abandons its pretensions to scientific discovery and consents to be ranked as a kind of poetry. 'A good symbol,' says Emerson, 'is a missionary to persuade thousands. The Vedas, the Edda, the Koran, are each remembered by its happiest figure. There is no more welcome gift to men than a new symbol. They assimilate themselves to it, deal with it in all ways, and it will last a hundred years. Then comes a new genius and brings another.' Our ideas of God and the soul are obviously subject to this symbolic mutation. They are not now what they were a century ago. They will not be a century hence what they are now. Such ideas constitute a kind of central energy in the human mind, capable, like the energy of the physical universe, of assuming various shapes and undergoing various transformations. They baffle and elude the theological mechanic who would carve them to dogmatic forms. They offer themselves freely to the poet who understands his vocation, and whose function is, or ought to be, to find 'local habitation' for thoughts woven into our subjective life, but which refuse to be mechanically defined.

We now stand face to face with the final problem. It is this: Are the brain, and the moral and intellectual processes known to be associated with the brain—and, as far as our experience goes, indissolubly associated—subject to the laws which we find paramount in physical nature? Is the will of man, in other words, free, or are it and nature equally 'bound fast in fate'? From this latter conclusion, after he had established it to the entire satisfaction of his understanding, the great German thinker Fichte recoiled. You will find the record of this struggle between head and heart in his book, entitled 'Die Bestimmung des Menschen'—The Vocation of Man.[1] Fichte was determined at all hazards to maintain his freedom, but the price he paid for it indicates the difficulty of the task. To escape from the iron necessity seen everywhere reigning in physical nature, he turned defiantly round upon nature and law, and affirmed both of them to be the products of his own mind. He was not going to be the slave of a thing which he had himself created. There is a good deal to be said in favour of this view, but few of us probably would be able to bring into play the solvent transcendentalism whereby Fichte melted his chains.

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[1] Translated by Dr. William Smith of Edinburgh; Trübner, 1873.

Why do some regard this notion of necessity with terror, while others do not fear it at all? Has not Carlyle somewhere said that a belief in destiny is the bias of all earnest minds? 'It is not Nature,' says Fichte, 'it is Freedom itself, by which the greatest and most terrible disorders incident to our race are produced. Man is the cruellest enemy of man.' But the question of moral responsibility here emerges, and it is the possible loosening of this responsibility that so many of us dread. The notion of necessity certainly failed to frighten Bishop Butler. He thought it untrue—even absurd—but he did not fear its practical consequences. He showed, on the contrary, in the 'Analogy,' that as far as human conduct is concerned, the two theories of free-will and necessity would come to the same in the end.

What is meant by free-will? Does it imply the power of producing events without antecedents?—of starting, as it were, upon a creative tour of occurrences without any impulse from within or from without? Let us consider the point. If there be absolutely or relatively no reason why a tree should fall, it will not fall; and if there be absolutely or relatively no reason why a man should act, he will not act. It is true that the united voice of this assembly could not persuade me that I have not, at this moment, the power to lift my arm if I wished to do so. Within this range the conscious freedom of my will cannot be questioned. But what about the origin of the 'wish'? Are we, or are we not, complete masters of the circumstances which create our wishes, motives, and tendencies to action? Adequate reflection will, I think, prove that we are not. What, for example, have I had to do with the generation and development of that which some will consider my total being, and others a most potent factor of my total being—the living, speaking organism which now addresses you? As stated at the beginning of this discourse, my physical and intellectual textures were woven *for* me, not *by* me. Processes in the conduct or regulation of which I had no share have made me what I am. Here, surely, if anywhere, we are as clay in the hands of the potter. It is the greatest of delusions to suppose that we come into this world as sheets of white paper on which the age can write anything it likes, making us good or bad, noble or mean, as the age pleases. The age can stunt, promote, or pervert pre-existent capacities, but it cannot create them. The worthy Robert Owen, who saw in external circumstances the great moulders of human character, was obliged to supplement his doctrine by making the man himself one of the circumstances. It is as fatal as it is cowardly to blink facts because they are not to our taste. How many disorders, ghostly and bodily, are transmitted to us by inheritance? In our courts of law, whenever it is a question whether a crime has been committed under the influence of insanity, the best guidance the judge and jury can have is derived from the parental antecedents of the accused. If among these insanity be exhibited in any marked degree, the presumption in the prisoner's favour is enormously enhanced, because the experience of life has taught both judge and jury that insanity is frequently transmitted from parent to child.

I met, some years ago, in a railway carriage the governor of one of our largest prisons. He was evidently an observant and reflective man, possessed of wide experience gathered in various parts of the world, and a thorough student of the duties of his vocation. He told me that the prisoners in his charge might be divided into three distinct classes. The first class consisted of persons who ought never to have been in prison. External accident, and not internal taint, had brought them within the grasp of the law, and what had happened to them might happen to most of us. They were essentially men of sound moral stamina, though wearing the prison garb. Then came the largest class, formed of individuals possessing no strong bias, moral or immoral, plastic to the touch of circumstances, which could mould them into either good or evil members of society. Thirdly came a class—happily not a large one—whom no kindness could conciliate and no discipline tame. They were sent into this world labelled 'incorrigible,' wickedness being stamped, as it were, upon their organisations. It was an unpleasant truth, but as a truth it ought to be faced. For such criminals the prison over which he ruled was certainly not the proper place. If confined at all, their prison should be on a desert island where the deadly contagium of their example could not taint the moral air. But the sea itself he was disposed to regard as a cheap and appropriate substitute for the island. It seemed to him evident that the State would benefit if prisoners of the first class were liberated; prisoners of the second class educated; and prisoners of the third class put compendiously under water.

It is not, however, from the observation of individuals that the argument against 'free-will,' as commonly understood, derives its principal force. It is, as already hinted, indefinitely strengthened when extended to the race. Most of you have been forced to listen to the outcries and denunciations which rang discordant through the land for some years after the publication of Mr. Darwin's 'Origin of Species.' Well, the world—even the clerical world—has for the most part settled down in the belief that Mr. Darwin's book simply reflects the truth of nature: that we who are now 'foremost in the files of time' have come to the front through almost endless stages of promotion from lower to higher forms of life.

If to any one of us were given the privilege of looking back through the æons across which life has crept towards its present outcome, his vision, according to Darwin, would ultimately reach a point when the progenitors of this assembly could not be called human. From that humble society, through the interaction of its members and the storing up of their best qualities, a better one emerged; from this again a better still; until at length, by the integration of infinitesimals through ages of amelioration, we came to be what we are to-day. We of this generation had no conscious share in the production of this grand and beneficent result. Any and every generation which preceded us had just as little share. The favoured organisms whose garnered excellence constitutes our present store owed their advantages, first, to what we in our ignorance are obliged to call 'accidental variation;' and, secondly, to a law of heredity in the passing of which our suffrages were not collected. With characteristic felicity and precision Mr. Matthew Arnold lifts this question into the free air of poetry, but not out of the atmosphere of truth, when he ascribes the process of amelioration to 'a power not ourselves which makes for righteousness.' If, then, our organisms, with all their tendencies and capacities, are given to us without our being consulted; and if, while capable of acting within certain limits in accordance with our wishes, we are not masters of the circumstances in which motives and wishes originate; if, finally, our motives and wishes determine our actions—in what sense can these actions be said to be the result of free-will?

Here, again, we are confronted with the question of moral responsibility, which, as it has been much talked of lately, it is desirable to meet. With the view of removing the fear of our falling back into the condition of 'the ape and tiger,' so sedulously excited by certain writers, I propose to grapple with this question in its rudest form, and in the most uncompromising way. 'If,' says the robber, the ravisher, or the murderer, 'I act because I must act, what right have you to hold me responsible for my deeds?' The reply is, 'The right of society to protect itself against aggressive and injurious forces, whether they be bond or free, forces of nature or forces of man.' 'Then,' retorts the criminal, 'you punish me for what I cannot help.' 'Let it be granted,' says society, 'but had you known that the treadmill or the gallows was certainly in store for you, you might have "helped." Let us reason the matter fully and frankly out. We may entertain no malice or hatred against you; it is enough that with a view to our own safety and purification we are determined that you and such as you shall not enjoy liberty of evil action in our midst. You, who have behaved as a wild beast, we claim the right to cage or kill as we should a wild beast. The public safety is a matter of more importance than the very limited chance of your moral renovation, while the knowledge that you have been hanged by the neck may furnish to others about to do as you have done the precise motive which will hold them back. If your act be such as to invoke a minor penalty, then not only others, but yourself, may profit by the punishment which we inflict. On the homely principle that "a burnt child dreads the fire," it will make you think twice before venturing on a repetition of your crime. Observe, finally, the consistency of our conduct. You offend, you say, because you cannot help offending, to the public detriment. We punish, is our reply, because we cannot help punishing, for the public good. Practically, then, as Bishop Butler predicted, we act as the world acted when it supposed the evil deeds of its criminals to be the products of free-will.'[1]

'What,' I have heard it argued, 'is the use of preaching about duty, if a man's predetermined position in the moral world renders him incapable of profiting by advice?' Who knows that he is incapable? The preacher's last word is a factor in the man's conduct, and it may be a most important factor, unlocking moral energies which might otherwise remain imprisoned and unused. If the preacher thoroughly feel that words of enlightenment, courage, and admonition enter into the list of forces employed by Nature herself for man's amelioration, since she gifted man with speech, he will suffer no paralysis to fall upon his tongue. Dung the fig-tree hopefully, and not until its barrenness has been demonstrated beyond a doubt let the sentence go forth, 'Cut it down, why cumbereth it the ground?'

I remember when a youth in the town of Halifax, some two-and-thirty years ago, attending a lecture given by a young man to a small but select audience. The aspect of the lecturer was earnest and practical, and his voice soon rivetted attention. He spoke of duty, defining it as a debt owed, and there was a kindling vigour in his words which must have strengthened the sense of duty in the minds of those who heard him. No speculations regarding the freedom of the will could alter the fact that the words of that young man did me good. His name was George Dawson. He also spoke, if you will allow me to allude to it, of a social subject much discussed at the time—the Chartist subject of 'levelling.' Suppose, he says, two men to be equal at night, and that one rises at six, while the other sleeps till nine next morning, what becomes of your levelling? And in so speaking he made himself the mouthpiece of Nature, which, as we have seen, secures advance, not by the reduction of all to a common level, but by the encouragement and conservation of what is best.

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[1] An eminent Church dignitary describes all this, not unkindly, as 'truculent logic.' I think it worthy of his Grace's graver consideration.

It may be urged that, in dealing as above with my hypothetical criminal, I am assuming a state of things brought about by the influence of religions which include the dogmas of theology and the belief in free-will—a state, namely, in which a moral majority control and keep in awe an immoral minority. The heart of man is deceitful above all things, and desperately wicked. Withdraw, then, our theologic sanctions, including the belief in free-will, and the condition of the race will be typified by the samples of individual wickedness which have been above adduced. We shall all, that is, become robbers, and ravishers, and murderers. From much that has been written of late it would seem that this astounding inference finds house-room in many minds. Possibly, the people who hold such views might be able to illustrate them by individual instances.

> The fear of hell's a hangman's whip,
> To keep the wretch in order.

Remove the fear, and the wretch, following his natural instinct, may become disorderly; but I refuse to accept him as a sample of humanity. 'Let us eat and drink, for to-morrow we die' is by no means the ethical consequence of a rejection of dogma. To many of you the name of George Jacob Holyoake is doubtless familiar, and you are probably aware that at no man in England has the term 'atheist' been more frequently pelted. There are, moreover, really few who have more completely liberated themselves from theologic notions. Among working-class politicians Mr. Holyoake is a leader. Does he exhort his followers to 'Eat and drink, for to-morrow we die'? Not so. In the August number of the 'Nineteenth Century' you will find these words from his pen: 'The gospel of dirt is bad enough, but the gospel of mere material comfort is much worse.' He contemptuously calls the Comtist championship of the working man, 'the championship of the trencher.' He would place 'the leanest liberty which brought with it the dignity and power of self-help' higher than 'any prospect of a full plate without it.' Such is the moral doctrine taught by this 'atheistic' leader; and no Christian, I apprehend, need be ashamed of it.

Most heartily do I recognise and admire the spiritual radiance, if I may use the term, shed by religion on the minds and lives of many personally known to me. At the same time I cannot but observe how signally, as regards the production of anything beautiful, religion fails in other cases. Its professor and defender is sometimes at bottom a brawler and a clown. These differences depend upon primary distinctions of character which religion does not remove. It may comfort some to know that there are amongst us many whom the gladiators of the pulpit would call 'atheists' and 'materialists,' whose lives, nevertheless, as tested by any accessible standard of morality, would contrast more than favourably with the lives of those who seek to stamp them with this offensive brand. When I say 'offensive,' I refer simply to the intention of those who use such terms, and not because atheism or materialism, when compared with many of the notions ventilated in the columns of religious newspapers, has any particular offensiveness for me. If I wished to find men who are scrupulous in their adherence to engagements, whose words are their bond, and to whom moral shiftiness of any kind is subjectively unknown; if I wanted a loving father, a faithful husband, an honourable neighbour, and a just citizen—I should seek him, and find him among the band of 'atheists' to which I refer. I have known some of the most pronounced among them not only in life but in death—seen them approaching with open eyes the inexorable goal, with no dread of a 'hangman's whip,' with no hope of a heavenly crown, and still as mindful of their duties, and as faithful in the discharge of them, as if their eternal future depended upon their latest deeds.

In letters addressed to myself, and in utterances addressed to the public, Faraday is often referred to as a sample of the association of religious faith with moral elevation. I was locally intimate with him for fourteen or fifteen years of my life, and had thus occasion to observe how nearly his character approached what might, without extravagance, be called perfection. He was strong but gentle, impetuous but self-restrained; a sweet and lofty courtesy marked his dealings with men and women; and though he sprang from the body of the people, a nature so fine might well have been distilled from the flower of antecedent chivalry. Not only in its broader sense was the Christian religion necessary to Faraday's spiritual peace, but in what many would call the narrow sense held by those described by Faraday himself as 'a very small and despised sect of power which has moulded us thus far has worked with stern tools upon a very rigid stuff. What it has done cannot be so readily undone; and it has endowed us with moral constitutions which take pleasure in the noble, the beautiful, and the true, just as surely as it has endowed us with sentient organisms, which find aloes bitter and sugar sweet. That power did not work with delusions, nor will it stay its hand when such are removed. Facts, rather than dogmas, have been its ministers—hunger and thirst, heat and cold, pleasure and pain, fervour, sympathy, aspiration, shame, pride, love, hate, terror, awe—such were the forces whose interaction and adjustment throughout an immeasurable past wove the triplex web of man's physical, intellectual, and moral nature, and such are the forces that will be effectual to the end.

You may retort that even on my own showing 'the power which makes for righteousness' *has* dealt in delusions; for it cannot be denied that the beliefs of religion, including the dogmas of theology and the freedom of the will, have had some effect in moulding the moral world Granted; but I do not think that this goes to the root of the matter. Are you quite sure that those beliefs and dogmas are primary, and not derived?—that they are not the *products*, instead of being the *creators*, of man's moral nature? I think it is in one of the Latter-Day Pamphlets that Carlyle corrects a reasoner, who deduced the nobility of man from a belief in heaven, by telling him that he puts the cart before the horse, the real truth being that the belief in heaven is derived from the nobility of man. The bird's instinct to weave its nest is referred to by Emerson as typical of the force which built cathedrals, temples, and pyramids:—

Knowest thou what wove yon woodbird's nest
Of leaves and feathers from her breast,
Or how the fish outbuilt its shell,
Painting with morn each annual cell?
Such and so grew these holy piles
While love and terror laid the tiles;
Earth proudly wears the Parthenon
As the best gem upon her zone;
And Morning opes with haste her lids
To gaze upon the Pyramids;
O'er England's abbeys bends the sky
As on its friends with kindred eye;
For out of Thought's interior sphere
These wonders rose to upper air,
And nature gladly gave them place,
Adopted them into her race,
And granted them an equal date
With Andes and with Ararat.

Surely, many utterances which have been accepted as descriptions ought to be interpreted as aspirations, or as having their roots in aspiration instead of in objective knowledge. Does the song of the herald angels, 'Glory to God in the highest, and on earth peace, goodwill toward men,' express the exaltation and the yearning of a human soul? or does it describe an optical and acoustical fact—a visible host and an audible song? If the former, the exaltation and the yearning are man's imperishable possession—a ferment long confined to individuals, but which may by-and-by become the leaven of the race. If the latter, then belief in the entire transaction is wrecked by non-fulfilment. Look to the East at the present moment as a comment on the promise of peace on earth and goodwill toward men. That promise is a dream ruined by the experience of eighteen centuries, and in that ruin is involved the claim of the 'heavenly host' to prophetic vision. But though the mechanical theory proves untenable, the immortal song and the feelings it expresses

ennobled until they finally emerged in the mythology and art of Greece:—

> Where still the magic robe of Poesy
> Wound itself lovingly around the Truth.[1]

As poets, the priesthood would have been justified, their deities, celestial and otherwise, with all their retinue and appliances, being more or less legitimate symbols and personifications of the aspects of nature and the phases of the human soul. The priests, however, or those among them who were mechanics, and not poets, claimed objective validity for their conceptions, and tried to base upon external evidence that which sprang from the innermost need and nature of man. It is against this objective rendering of the emotions—this thrusting into the region of fact and positive knowledge of conceptions essentially ideal and poetic—that science, consciously or unconsciously, wages war. Religious feeling is as much a verity as any other part of human consciousness; and against it, on its subjective side, the waves of science beat in vain. But when, manipulated by the constructive imagination, mixed with imperfect or inaccurate historic data, and moulded by misapplied logic, this feeling makes claims which traverse our knowledge of nature, science, as in duty bound, stands as a hostile power in its path. It is against the mythologic scenery, if I may use the term, rather than against the life and substance of religion, that Science enters her protest. Sooner or later among thinking people, that scenery will be taken for what it is worth—as an effort on the part of man to bring the mystery of life and nature within the range of his capacities; as a temporary and essentially fluxional render-

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[1] 'Da der Dichtung zauberische Hülle
Sich noch lieblich um die Wahrheit wand.'—*Schiller*.

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ing in terms of knowledge of that which transcends all knowledge, and admits only of ideal approach.

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[1] 'Da der Dichtung zauberische Hülle
Sich noch lieblich um die Wahrheit wand.'—*Schiller.*

The signs of the times, I think, point in this direction. It is, for example, the obvious aim of Mr. Matthew Arnold to protect, amid the wreck of dogma, the poetic basis of religion. And it is to be remembered that under the circumstances poetry may be the purest accessible truth. In other influential quarters a similar spirit is at work. In a remarkable article published by Professor Knight of St. Andrews in the September number of the 'Nineteenth Century,' amid other free utterances, we have this one:—'If matter is not eternal, its first emergence into being is a miracle beside which all others dwindle into absolute insignificance. But, as has often been pointed out, the process is unthinkable; the sudden apocalypse of a material world out of blank nonentity cannot be imagined;[1] its emergence into order out of chaos when "without form and void" of life, *is merely a poetic rendering of the doctrine of its slow evolution.*' These are all bold words to be spoken before the moral philosophy class of a Scotch university, while those I have underlined show a remarkable freedom of dealing with the sacred text. They repeat in terser language what I ventured to utter four years ago regarding the Book of Genesis. 'Profoundly interesting and indeed pathetic to me are those attempts of the opening mind of man to appease its hunger for a Cause. But the Book of Genesis has no voice in scientific questions. *It is a poem, not a scientific treatise.* In the former aspect it is for ever beautiful; in the latter it has been, and it will continue to be, purely obstructive and hurtful.' My agree-

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[1] Professor Knight will have to reckon with the English Marriage Service, one of whose Collects begins thus: 'O God, who by thy mighty power hast made all things of nothing.'

The quantity of these latter possessed by the
not simply diffused among their descend-
in that case the last must feel more feebly than
The sensations and feelings must necessarily
back to the flour, where they exist, weak and
and not concentrated as they are in the
We may not be able to taste or smell alcohol
of fermented cherries, but by distillation we
from them concentrated Kirschwasser. Hence
comparison of the brain to a still, which
the sensation and feeling, pre-existing, but
in the food.

' says Mr. Holyoake,² 'grow as the
experience expands. They are not inventions,
of the state of a question. No man
through a discovery at once.' Thus Descartes's
matter, and his explanation of motion, would
as trivial by a physiologist or a crystallo-
present day. They are not descriptions
of the question. And yet a desire some-
in distinguished quarters to bind us
which passed muster in the infancy
are wholly incompatible with
Mr. Martineau, I think,
to views enunciated by
' That definitions
is in accordance
practice. When,
started, it was
would be trans-
example of
itudinal

Against this not
Toland, whose
yard, strenuously
be an inherent attr
matter was at rest,
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ment with Professor Knight extends still further. 'Does the vital,' he asks, 'proceed by a still remoter development from the non-vital? Or was it created by a fiat of volition? Or'—and here he emphasises his question—'*has it always existed in some form or other as an eternal constituent of the universe?* I do not see,' he replies, 'how we can escape from the last alternative.' With the whole force of my conviction I say, Nor do I, though our modes of regarding the 'eternal constituent' may not be the same.

When matter was defined by Descartes, he deliberately excluded the idea of force or motion from its attributes and from his definition. *Extension* only was taken into account. And, inasmuch as the impotence of matter to generate motion was assumed, its observed motions were referred to an external cause. God, resident outside of matter, gave the impulse. In this connection the argument in Young's 'Night Thoughts' will occur to most readers:—

Who Motion foreign to the smallest grain
Shot through vast masses of enormous weight?
Who bid brute Matter's restive lump assume
Such various forms, and gave it wings to fly?

Against this notion of Descartes the great deist John Toland, whose ashes lie unmarked in Putney Churchyard, strenuously contended. He affirmed motion to be an inherent attribute of matter—that no portion of matter was at rest, and that even the most quiescent solids were animated by a motion of their ultimate particles. The success of his contention, according to the learned and laborious Dr. Berthold,[1] entitles Toland to be regarded as the founder of that *monistic* doctrine which is now so rapidly spreading.

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[1] 'John Toland und der Monismus der Gegenwart,' Heidelberg, Carl Winter.

It seems to me that the idea of vitality entertained in our day by Professor Knight, closely resembles the idea of motion entertained by his opponents in Toland's day. Motion was then virtually asserted to be a thing *sui generis*, distinct from matter, and incapable of being generated out of matter. Hence the obvious inference when matter was observed to move. It was the vehicle of an energy not its own—the repository of forces impressed on it from without—the purely passive recipient of the shock of the Divine. The logical form continues, but the subject-matter is changed. 'The evolution of nature,' says Professor Knight, 'may be a fact; a daily and hourly apocalypse. But we have no evidence of the non-vital passing into the vital. Spontaneous generation is, as yet, an imaginative guess, unverified by scientific tests. And matter is not itself alive. Vitality, whether seen in a single cell of protoplasm or in the human brain, is a thing *sui generis*, distinct from matter, and incapable of being generated out of matter.' It may be, however, that, in process of time, vitality will follow the example of motion, and, after the necessary antecedent wrangling, take its place among the attributes of that 'universal mother' who has been so often misdefined.

That 'matter is not itself alive' Professor Knight seems to regard as an axiomatic truth. Let us place in contrast with this the notion entertained by the philosopher Ueberweg, one of the subtlest heads that Germany has produced. 'What occurs in the brain' says Ueberweg 'would, in my opinion, not be possible, if the process which here appears in its greatest concentration did not obtain generally, only in a vastly diminished degree. Take a pair of mice and a cask of flour. By copious nourishment the animals increase and multiply, and in the same proportion sensations and feelings augment. The quantity of these latter possessed by the first pair, is not simply diffused among their descendants, for in that case the last must feel more feebly than the first. The sensations and feelings must necessarily be referred back to the flour, where they exist, weak and pale it is true, and not concentrated as they are in the brain.'[1] We may not be able to taste or smell alcohol in a tub of fermented cherries, but by distillation we obtain from them concentrated Kirschwasser. Hence Ueberweg's comparison of the brain to a still, which concentrates the sensation and feeling, pre-existing, but diluted in the food.

'Definitions,' says Mr. Holyoake,[2] 'grow as the horizon of experience expands. They are not inventions, but descriptions of the state of a question. No man sees all through a discovery at once.' Thus Descartes's notion of matter, and his explanation of motion, would be put aside as trivial by a physiologist or a crystallographer of the present day. They are not descriptions of the state of the question. And yet a desire sometimes shows itself in distinguished quarters to bind us down to conceptions which passed muster in the infancy of knowledge, but which are wholly incompatible with our present enlightenment. Mr. Martineau, I think, errs when he seeks to hold me to views enunciated by 'Democritus and the mathematicians.' That definitions should change as knowledge advances is in accordance both with sound sense and scientific practice. When, for example, the undulatory theory was started, it was not imagined that the vibrations of light could be transverse to the direction of propagation. The example of sound was at hand, which was a case of longitudinal vibration. Now the substitution of transverse for longitudinal vibrations in the case of light involved a radical change of conception as to the mechanical properties of the luminiferous medium. But though this change went so far as to fill space with a substance, possessing the properties of a solid, rather than those of a gas, the change was accepted, because the newly discovered facts imperatively demanded it. Following Mr. Martineau's example, the opponent of the undulatory theory might effectually twit the holder of it on his change of front. 'This ether of yours,' he might say, 'alters its style with every change of service. Starting as a beggar, with scarce a rag of 'property' to cover its bones, it turns up as a prince when large undertakings are wanted. You had some show of reason when, with the case of sound before you, you assumed your ether to be a gas in the last extremity of attenuation. But now that new service is rendered necessary by new facts, you drop the beggar's rags, and accomplish an undertaking, great and princely enough in all conscience; for it implies that not only planets of enormous weight, but comets with hardly any weight at all, fly through your hypothetical solid without perceptible loss of motion.' This would sound very cogent, but it would be very vain. Equally vain, in my opinion, is Mr. Martineau's contention that we are not justified in modifying, in accordance with advancing knowledge, our notions of matter.

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[1] Letter to Lange: 'Geschichte des Materialismus,' zweite Aufl., vol. ii. p. 521.

[2] 'Nineteenth Century,' September 1878.

Before parting from Professor Knight, let me commend his courage as well as his insight. We have heard much of late of the peril to morality involved in the decay of religious belief. What Mr. Knight says under this head is worthy of all respect and attention. 'I admit,' he writes, 'that were it proved that the moral faculty was derived as well as developed, its present decisions would not be invalidated. The child of experience has a father whose teachings are grave, peremptory, and august; and an earthborn rule may be as stringent as any derived from a celestial source. It does not even follow that a belief in the material origin of spiritual existence, accompanied by a corresponding decay of belief in immortality, must *necessarily* lead to a relaxation of the moral fibre of the race. It is certain that it has often done so.[1] But it is equally certain that there have been individuals, and great historical communities, in which the absence of the latter belief has neither weakened moral earnestness, nor prevented devotional fervour.' I have elsewhere stated that some of the best men of my acquaintance—men lofty in thought and beneficent in act—belong to a class who assiduously let the belief referred to alone. They derive from it neither stimulus nor inspiration, while—I say it with regret—were I in quest of persons who, in regard to the finer endowments of human character, are to be ranked with the unendowed, I should find some characteristic samples among the noisier defenders of the orthodox belief. These, however, are but 'hand-specimens' on both sides; the wider data referred to by Professor Knight constitute, therefore, a welcome corroboration of my experience. Again, my excellent critic, Professor Blackie, describes Buddha as being 'a great deal more than a prophet; a rare, exceptional, and altogether transcendental incarnation of moral perfection.'[2] And yet, 'what Buddha preached was a gospel of pure human ethics, divorced not only from Brahma and the Brahminic Trinity, but even from the existence of God.'[1] These civilised and gallant voices from the North contrast pleasantly with the barbarous whoops which sometimes come to us along the same meridian.

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[1] Is this really certain? Instead of standing in the relation of cause and effect, may not the 'decay' and 'relaxation' be merely coexistent, both, perhaps, flowing from common historic antecedents?

[2] 'Natural History of Atheism,' p. 136.

Looking backwards from my present standpoint over the earnest past, a boyhood fond of play and physical action, but averse to schoolwork, lies before me. The aversion did not arise from intellectual apathy or want of appetite for knowledge, but simply from the fact that my earliest teachers lacked the power of imparting vitality to what they taught. Athwart all play and amusement, however, a thread of seriousness ran through my character; and many a sleepless night of my childhood has been passed, fretted by the question 'Who made God?' I was well versed in Scripture; for I loved the Bible, and was prompted by that love to commit large portions of it to memory. Later on I became adroit in turning my Scriptural knowledge against the Church of Rome, but the characteristic doctrines of that Church marked only for a time the limits of enquiry. The eternal Sonship of Christ, for example, as enunciated in the Athanasian Creed, perplexed me. The resurrection of the body was also a thorn in my mind, and here I remember that a passage in Blair's 'Grave' gave me momentary rest.

> Sure the same power
> That rear'd the piece at first and took it down
> Can reassemble the loose, scatter'd parts
> And put them as they were.

The conclusion seemed for the moment entirely fair, but with further thought, my difficulties came back to me. I had seen cows and sheep browsing upon churchyard grass, which sprang from the decaying mould of dead men. The flesh of these animals was undoubtedly a modification of human flesh, and the persons who fed upon them were as undoubtedly, in part, a more remote modification of the same substance. I figured the self-same molecules as belonging first to one body and afterwards to a different one, and I asked myself how two bodies so related could possibly arrange their claims at the day of resurrection. The scattered parts of each were to be reassembled and set as they were. But if handed over to the one, how could they possibly enter into the composition of the other? Omnipotence itself, I concluded, could not reconcile the contradiction. Thus the plank which Blair's mechanical theory of the resurrection brought momentarily into sight, disappeared, and I was again cast abroad on the waste ocean of speculation.

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[1] 'Natural History of Atheism,' p. 125.

At the same time I could by no means get rid of the idea that the aspects of nature and the consciousness of man implied the operation of a power altogether beyond my grasp—an energy the thought of which raised the temperature of the mind, though it refused to accept shape, personal or otherwise, from the intellect. Perhaps the able critics of the 'Saturday Review' are justified in speaking as they sometimes do of Mr. Carlyle. They owe him nothing, and have a right to announce the fact in their own way. I, however, owe him a great deal, and am also in honour bound to acknowledge the debt. Few, perhaps, who are privileged to come into contact with that illustrious man have shown him a sturdier front than I have, or in discussing modern science have more frequently withstood him. But I could see that his contention at bottom always was that the human soul has claims and yearnings which physical science cannot satisfy. England to come will assuredly thank him for his affirmation of the ethical and ideal side of human nature. Be this as it may, at the period now reached in my story the feeling referred to was indefinitely strengthened, my whole life being at the same time rendered more earnest, resolute, and laborious by the writings of Carlyle. Others also ministered to this result. Emerson kindled me, while Fichte powerfully stirred my moral pulse.[1] In this relation I cared little for political theories or philosophic systems, but a great deal for the propagated life and strength of pure and powerful minds. In my later school-days, under a clever teacher, some knowledge of mathematics and physics had been picked up: my stock of both was, however, scanty, and I resolved to augment it. But it was really with the view of learning whether mathematics and physics could help me in other spheres, rather than with the desire of acquiring distinction in either science, that I ventured, in 1848, to break the continuity of my life, and devote the meagre funds then at my disposal to the study of science in Germany.

But science soon fascinated me on its own account. To carry it duly and honestly out, moral qualities were incessantly invoked. There was no room allowed for insincerity—no room even for carelessness. The edifice of science had been raised by men who had unswervingly followed the truth as it is in nature; and in doing so had often sacrificed interests which are usually potent in this world. Among these rationalistic men of Germany I found conscientiousness in work as much insisted on as it could be among theologians. And why, since they had not the rewards or penalties of the theologian to offer to their disciples? Because they assumed, and were justified in assuming, that those whom they addressed had that within them which would respond to their appeal. If Germany should ever change for something less noble the simple earnestness and fidelity to duty, which in those days characterised her teachers, and through them her sons generally, it will not be because of rationalism. Such a decadent Germany might coexist with the most rampant rationalism without their standing to each other in the relation of cause and effect.

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[1] The reader will find in the Seventeenth Lecture of Fichte's course on the 'Characteristics of the Present Age' a sample of the vital power of this philosopher.

My first really laborious investigation, conducted jointly with my friend Professor Knoblauch, landed me in a region which harmonised with my speculative tastes. It was essentially an enquiry in molecular physics, having reference to the curious, and then perplexing, phenomena exhibited by crystals when freely suspended in the magnetic field. I here lived amid the most complex operations of magnetism in its twofold aspect of an attractive and a repellent force. Iron was attracted by a magnet, bismuth was repelled, and the crystals operated on ranged themselves under these two heads. Faraday and Plücker had worked assiduously at the subject, and had invoked the aid of new forces to account for the phenomena. It was soon, however, found that the displacement in a crystal of an atom of the iron class by an atom of the bismuth class, involving no change of crystalline form, produced a complete reversal of the phenomena. The lines through the crystal which were in the one case drawn towards the poles of the magnet, were driven, in the other case, from these poles. By such instances and the reasoning which they suggested, magne-crystallic action was proved to be due, not to the operation of new forces, but to the modification of the old ones by molecular arrangement. Whether diamagnetism, like magnetism, was a polar force, was in those days a subject of the most lively contention. It was finally proved to be so; and the most complicated cases of magne-crystallic action were immediately shown to be simple mechanical consequences of the principle of diamagnetic polarity. These early researches, which occupied in all five years of my life, and throughout which the molecular architecture of crystals was an incessant subject of mental contemplation, gave a tinge and bias to my subsequent scientific thought, and their influence is easily traced in my subsequent enquiries. For example, during nine years of labour on the subject of radiation, heat and light were handled throughout by me, not as ends, but as instruments by the aid of which the mind might perchance lay hold upon the ultimate particles of matter.

Scientific progress depends mainly upon two factors which incessantly interact—the strengthening of the mind by exercise, and the illumination of phenomena by knowledge. There seems no limit to the insight regarding physical processes which this interaction carries in its train. Through such insight we are enabled to enter and explore that subsensible world into which all natural phenomena strike their roots, and from which they derive nutrition. By it we are enabled to place before the mind's eye atoms and atomic motions which lie far beyond the range of the senses, and to apply to them reasoning as stringent as that applied by the mechanician to the motions and collisions of sensible masses. But once committed to such conceptions, there is a risk of being irresistibly led beyond the bounds of inorganic nature. Even in those early stages of scientific growth, I found myself more and more compelled to regard not only crystals, but organic structures, the body of man inclusive, as cases of molecular architecture, infinitely more complex, it is true, than those of inorganic nature, but reducible, in the long run, to the same mechanical laws. In ancient journals I find recorded ponderings and speculations relating to these subjects, and attempts made, by reference to magnetic and crystalline phenomena, to present some satisfactory image to the mind of the way in which plants and animals are built up. Perhaps I may be excused for noting a sample of these early speculations, already possibly known to a few of my readers, but which here finds a more suitable place than that which it formerly occupied.

Sitting, in the summer of 1855, with my friend Dr. Debus under the shadow of a massive elm on the bank of a river in Normandy, the current of our thoughts and conversation was substantially this:—We regarded the tree above us. In opposition to gravity its molecules had ascended, diverged into branches, and budded into innumerable leaves. What caused them to do so—a power external to themselves, or an inherent force? Science rejects the outside builder; let us, therefore, consider from the other point of view the experience of the present year. A low temperature had kept back for weeks the life of the vegetable world. But at length the sun gained power—or, rather, the cloud-screen which our atmosphere had drawn between him and us was removed—and life immediately kindled under his warmth. But what is life, and how can solar light and heat thus affect it? Near our elm was a silver birch, with its leaves rapidly quivering in the morning air. We had here motion, but not the motion of life. Each leaf moved as a mass under the influence of an outside force, while the motion of life was inherent and molecular. How are we to figure this molecular motion—the forces which it implies, and the results which flow from them? Suppose the leaves to be shaken from the tree and enabled to attract and repel each other. To fix the ideas, suppose the point of each leaf to repel all the other points and to attract the roots, and the root of each leaf to repel all other roots, but to attract the points. The leaves would then resemble an assemblage of little magnets abandoned freely to the interaction of their own forces. In obedience to these they would arrange themselves, and finally assume positions of rest, forming a coherent mass. Let us suppose the breeze, which now causes them to quiver, to disturb the assumed equilibrium. As often as disturbed there would be a constant effort on the part of the leaves to re-establish it; and in making this effort the mass of leaves would pass through different shapes and forms. If other leaves, moreover, were at hand endowed with similar forces, the attraction would extend to them—a growth of the mass of leaves being the consequence.

We have strong reason for assuming that the ultimate particles of matter—the atoms and molecules of which it is made up—are endowed with forces coarsely typified by those here ascribed to the leaves. The phenomena of crystallisation lead, of necessity, to this conception of molecular polarity. Under the operation of such forces the molecules of a seed, like our fallen leaves in the first instance, take up positions from which they would never move if undisturbed by an external impulse. But solar light and heat, which come to us as waves through space, are the great agents of molecular disturbance. On the inert molecules of seed and soil these waves impinge, disturbing the atomic equilibrium, which there is an immediate effort to restore. The effort, incessantly defeated—for the waves continue to pour in—is incessantly renewed; in the molecular struggle matter is gathered from the soil and from the atmosphere, and built, in obedience to the

ennobled until they finally emerged in the mythology and art of Greece:—

> Where still the magic robe of Poesy
> Wound itself lovingly around the Truth.[1]

As poets, the priesthood would have been justified, their deities, celestial and otherwise, with all their retinue and appliances, being more or less legitimate symbols and personifications of the aspects of nature and the phases of the human soul. The priests, however, or those among them who were mechanics, and not poets, claimed objective validity for their conceptions, and tried to base upon external evidence that which sprang from the innermost need and nature of man. It is against this objective rendering of the emotions—this thrusting into the region of fact and positive knowledge of conceptions essentially ideal and poetic—that science, consciously or unconsciously, wages war. Religious feeling is as much a verity as any other part of human consciousness; and against it, on its subjective side, the waves of science beat in vain. But when, manipulated by the constructive imagination, mixed with imperfect or inaccurate historic data, and moulded by misapplied logic, this feeling makes claims which traverse our knowledge of nature, science, as in duty bound, stands as a hostile power in its path. It is against the mythologic scenery, if I may use the term, rather than against the life and substance of religion, that Science enters her protest. Sooner or later among thinking people, that scenery will be taken for what it is worth—as an effort on the part of man to bring the mystery of life and nature within the range of his capacities; as a temporary and essentially fluxional render-

tinuity between us and our loftier brothers yet to come.

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[1] 'Da der Dichtung zauberische Hülle
Sich noch lieblich um die Wahrheit wand.'—*Schiller*.

'We have guarded ourselves against saying that the inferring of thought from material combinations and arrangements would be an inference *à priori*. The inference meant would be the same in kind as that which the observation of the effects of food and drink upon the mind would enable us to make, differing only from the latter in the degree of analytical insight which we suppose attained. Given the masses and distances of the planets, we can infer the perturbations consequent on their mutual attractions. Given the nature of a disturbance in water, air, or ether—knowing the physical qualities of the medium we can infer how its particles will be affected. In all this we deal with physical laws. The mind runs with certainty along the line of thought which connects the phenomena, and from beginning to end there is no break in the chain. But when we endeavour to pass by a similar process from the phenomena of physics to those of thought, we meet a problem which transcends any conceivable expansion of the powers which we now possess. We may think over the subject again and again, but it eludes all intellectual presentation. We stand at length face to face with the Incomprehensible. The territory of physics is wide, but it has its limits from which we look with vacant gaze into the region beyond. Let us follow matter to its utmost bounds, let us claim it in all its forms—even in the muscles, blood, and brain of man himself—as ours to experiment with and to speculate upon. Casting the term "vital force" from our vocabulary, let us reduce, if we can, the visible phenomena of life to mechanical attractions and repulsions. Having thus exhausted physics, and reached its very rim, a mighty Mystery still looms beyond us. We have, in fact, made no step towards its solution. And thus it will ever loom, compelling the philosophies of successive ages to confess that

> "We are such stuff
> As dreams are made of, and our little life
> Is rounded by a sleep."'

In my work on 'Heat,' published in 1863 and republished many times since, I employ the precise language thus extracted from the 'Saturday Review.'

The distinction is here clearly brought out which I had resolved at all hazards to draw—that, namely, between what men knew or might know, and what they could never hope to know. Impart simple magnifying power to our present vision, and the atomic motions of the brain itself might be brought into view. Compare these motions with the corresponding states of consciousness, and an empirical nexus might be established; but 'we try to soar in a vacuum when we endeavour to pass by logical deduction from the one to the other.' Among these brain-effects a new product appears which defies mechanical treatment. We cannot deduce motion from consciousness or consciousness from motion as we deduce one motion from another. Nevertheless observation is open to us, and by it relations may be established which are at least as valid as those of the deductive reason. The difficulty may really lie in the attempt to convert a datum into an inference—an ultimate fact into a product of logic. My desire for the moment, however, is not to theorise, but to let facts speak in reply to accusation.

The most 'materialistic' speculation for which I was responsible, prior to the 'Belfast Address,' is embodied in the following extract from a brief article written as far back as 1865 :—' Supposing the molecules of the human body, instead of replacing others, and thus renewing a pre-existing form, to be gathered first-hand from nature, and placed in the exact relative positions which they occupy in the body. Supposing them to have the same forces and distribution of forces, the same motions and distribution of motions—would this organised concourse of molecules stand before us as a sentient, thinking being? There seems no valid reason to assume that it would not. Or supposing a planet carved from the sun, set spinning round an axis, and sent revolving round the sun at a distance equal to that of our earth, would one consequence of the refrigeration of the mass be the development of organic forms? I lean to the affirmative.' This is plain speaking, but it is without 'dogmatism.' An opinion is expressed, a belief, a *leaning*—not an established 'doctrine.'

The burthen of my writings in this connection is as much a recognition of the weakness of science as an assertion of its strength. In 1867, I told the working men of Dundee that while making the largest demand for freedom of investigation; while considering science to be alike powerful as an instrument of intellectual culture, and as a ministrant to the material wants of men; if asked whether science has solved, or is likely in our day to solve, 'the problem of the universe,' I must shake my head in doubt. I compare the mind of man to a musical instrument with a certain range of notes, beyond which in both directions exists infinite silence. The phenomena of matter and force come within our intellectual range; but behind, and above, and around us the real mystery of the universe lies unsolved, and, as far as we are concerned, is incapable of solution.

While refreshing my mind on these old themes I appear to myself as a person possessing one idea, which so over-masters him that he is never weary of repeating it. That idea is the polar conception of the grandeur and the littleness of man—the vastness of his range in some respects and directions, and his powerlessness to take a single step in others. In 1868, before the Mathematical and Physical Section of the British Association, then assembled at Norwich, I repeat the same well-worn note:—

'In thus affirming the growth of the human body to be mechanical, and thought as exercised by us to have its correlative in the physics of the brain, the position of the "materialist," as far as that position is tenable, is stated. I think the materialist will be able finally to maintain this position against all attacks, but I do not think he can pass beyond it. The problem of the connection of body and soul is as insoluble in its modern form as it was in the pre-scientific ages. Phosphorus is a constituent of the human brain, and a trenchant German writer has exclaimed, "Ohne Phosphor kein gedanke!" That may or may not be the case; but, even if we knew it to be the case, the knowledge would not lighten our darkness. On both sides of the zone here assigned to the materialist, he is equally helpless. If you ask him whence is this "matter" of which we have been discoursing—who or what divided it into molecules, and impressed upon them this necessity of running into organic forms—he has no answer. Science is also mute in regard to such questions. But if the materialist is confounded and science is rendered dumb, who else is prepared with an answer? Let us lower our heads and acknowledge our ignorance, priest and philosopher, one and all.'

The roll of echoes which succeeded the Lecture delivered by Professor Virchow at Munich on September 22, 1877, was long and loud. The 'Times' published a nearly full translation of the lecture, and it was eagerly commented on in other journals. Glances from it to an

Address delivered by me before the Midland Institute in the autumn of 1877, and published in this volume, were very frequent. Professor Virchow was held up to me in some quarters as a model of philosophic caution, who by his reasonableness reproved my rashness, and by his depth reproved my shallowness. With true theologic courtesy I was sedulously emptied, not only of the 'principles of scientific thought,' but of 'common modesty' and 'common sense.' And though I am indebted to Professor Clifford for recalling in the 'Nineteenth Century' for April the public mind in this connection from heated fancy to sober fact, I do not think a brief additional examination of Virchow's views, and of my relation to them, will be out of place here.

The key-note of his position is struck in the preface to the excellent English translation of his lecture—a preface written expressly by himself. 'Nothing,' he says, 'was farther from his intention than any wish to disparage the great services rendered by Mr. Darwin to the advancement of biological science, of which no one has expressed more admiration than himself. On the other hand, it seemed high time to him to enter an energetic protest against the attempts that are made to proclaim the problems of research as actual facts, and the opinions of scientists as established science.' On the ground, among others, that it promotes the pernicious delusions of the Socialist, Virchow considers the theory of evolution dangerous; but his fidelity to truth is so great that he would brave the danger and teach the theory, if it were only proved. 'However dangerous the state of things might be, let the confederates be as mischievous as they might, still I do not hesitate to say that from the moment when we had become convinced that the evolution theory was a perfectly established doctrine—so certain that we could pledge our oath to it, so sure that we could say, "Thus it is"—from that moment we could not dare to feel any scruple about introducing it into our actual life, so as not only to communicate it to every educated man, but to impart it to every child, to make it the foundation of our whole ideas of the world, of society, and the State, and to base upon it our whole system of education. This I hold to be a necessity.'

It would be interesting to know the persons designated by the pronoun 'we' in the first sentence of the foregoing quotation. No doubt Professor Haeckel would accept this canon in all its fulness, and found on it his justification. He would say without hesitation: 'I *am* convinced that the theory of evolution is a perfectly established doctrine, and hence on your own showing I am justified in urging its introduction into our schools.' It is plain, however, that Professor Virchow would not accept this retort as valid. His 'we' must cover something more than Professor Haeckel. It would probably cover more even than the audience he addressed; for he would hardly affirm, even if every one of his hearers accepted the theory of evolution, that that would be a sufficient warrant for forcing it upon the public at large. His 'we,' I submit, needs definition. If he means that the theory of evolution ought to be introduced into our schools, not when experts are agreed as to its truth, but when the community is prepared for its introduction, then, I think, he is right, and that, as a matter of social policy, Dr. Haeckel would be wrong in seeking to antedate the period of its introduction. In dealing with the community great changes must have *timeliness* as well as truth upon their side. But if the mouths of thinkers be stopped, the necessary social preparation will be impossible; an unwholesome divorce will be established between the expert and the public, and the slow and natural process of leavening the social lump by discovery and discussion will be displaced by something far less safe and salutary.

The burthen, however, of this celebrated lecture is a warning that a marked distinction ought to be made between that which is experimentally proved, and that which is still in the region of speculation. As to the latter, Virchow by no means imposes silence. He is far too sagacious a man to commit himself, at the present time of day, to any such absurdity. But he insists that it ought not to be put on the same evidential level as the former. 'It ought,' as he poetically expresses it, 'to be written in small letters under the text.' The audience ought to be warned that the speculative matter is only *possible*, not *actual* truth —that it belongs to the region of 'belief,' and not to that of demonstration. As long as a problem continues in this speculative stage it would be mischievous, he considers, to teach it in our schools. 'We ought not,' he urges, 'to represent our conjecture as a certainty, nor our hypothesis as a doctrine: this is inadmissible.' With regard to the connection between physical processes and mental phenomena he says: 'I will, indeed, willingly grant that we can find certain gradations, certain definite points at which we trace a passage from mental processes to processes purely physical, or of a physical character. Throughout this discourse I am not asserting that it will never be possible to bring psychical processes into an immediate connection with those that are physical. All I say is that we have *at present* no right to set up this *possible* connection as a *doctrine* of science.' In the next paragraph he reiterates his position with reference to the introduction of such topics into school teaching. 'We must draw,' he says, 'a strict distinction between what we wish to *teach*, and what we wish to *search for.* The objects of our research are expressed as problems (or hypotheses). *We need not keep them to ourselves; we are ready to communicate them to all the world*, and say "There is the problem; that is what we strive for." . . . The investigation of such problems, in which the whole nation may be interested, cannot be restricted to any one. This is Freedom of Enquiry. But the problem (or hypothesis) is not, without further debate, to be made *a doctrine*.' He will not concede to Dr. Haeckel 'that it is a question for the schoolmasters to decide, whether the Darwinian theory of man's descent should be at once laid down as the basis of instruction, and the protoplastic soul be assumed as the foundation of all ideas concerning spiritual being.' The Professor concludes his lecture thus: 'With perfect truth did Bacon say of old "*Scientia est potentia.*" But he also defined that knowledge; and the knowledge he meant was not speculative knowledge, not the knowledge of hypotheses, but it was objective and actual knowledge. Gentlemen, I think we should be abusing our power, we should be imperilling our power, unless in our teaching we restrict ourselves to this perfectly safe and unassailable domain. From this domain *we may make incursions into the field of problems*, and I am sure that every venture of that kind will then find all needful security and support.' I have emphasised by italics two sentences in the foregoing series of quotations; the other italics are the author's own.

Virchow's position could not be made clearer by any comments of mine than he has here made it himself. That position is one of the highest practical importance. 'Throughout our whole German Fatherland,' he says, 'men are busied in renovating, extending, and developing the system of education, and in inventing fixed forms in which to mould it. On the threshold of coming events stands the Prussian law of education. In all the German States larger schools are being built, new educational establishments are set up, the universities are extended, "higher" and "middle" schools are founded. Finally comes the question, What is to be the chief substance of the teaching?' What Virchow thinks it ought and ought not to be, is disclosed by the foregoing quotations. There ought to be a clear distinction made between science in the state of hypothesis, and science in the state of fact. In school teaching the former ought to be excluded. And, as he assumes it to be still in its hypothetical stage, the ban of exclusion ought, he thinks, to fall upon the theory of evolution.

I now freely offer myself for judgment before the tribunal whose law is here laid down. First and foremost, then, I have never advocated the introduction of the theory of evolution into our schools. I should even be disposed to resist its introduction before its meaning had been better understood and its utility more fully recognised than it is now by the great body of the community. The theory ought, I think, to bide its time until the free conflict of discovery, argument, and opinion has won for it this recognition. A necessary condition here, however, is that free discussion should not be prevented, either by the ferocity of reviewers or the arm of the law; otherwise, as I said before, the work of social preparation cannot go on. On this count, then, I claim acquittal, being for the moment on the side of Virchow.

Besides the duties of the chair, which I have been privileged to occupy in London for more than a quarter of a century, and which never involved a word on my part, *pro* or *con.*, in reference to the theory of evolution, I have had the honour of addressing audiences in Liverpool, Belfast, and Birmingham; and in these addresses the theory of evolution, and the connected doctrine of spontaneous generation, have been more or less touched upon. Let us now examine whether in my references I have departed from the views of Virchow or not.

In the Liverpool discourse, after speaking of the theory of evolution when applied to the primitive condition of matter, as belonging to 'the dim twilight of conjecture,' and affirming that 'the certainty of experimental enquiry is here shut out,' I sketch the nebular theory as enunciated by Kant and Laplace, and afterwards proceed thus: 'Accepting some such view of the construction of our system *as probable*, a desire immediately arises to connect the present life of our planet with the past. We wish to know something of our remotest ancestry. On its first detachment from the sun, life, as we understand it, could not have been present on the earth. How, then, did it come there? The thing to be encouraged here is a reverent freedom —a freedom preceded by the hard discipline which checks licentiousness in speculation—while the thing to be repressed, both in science and out of it, is dogmatism. And here I am in the hands of the meeting, willing to end but ready to go on. *I have no right to intrude upon you unasked the unformed notions which are floating like clouds, or gathering to more solid consistency in the modern speculative mind.*'

I then notice more especially the basis of the theory. 'Those who hold the doctrine of evolution *are by no means ignorant of the uncertainty of their data, and they only yield to it a provisional assent.* They regard the nebular hypothesis as probable; and, in the utter absence of any proof of the illegality of the act, they prolong the method of nature from the present into the past. Here the observed uniformity of nature is their only guide. Having determined the elements of their curve in a world of observation and experiment, they prolong that curve into an antecedent world, and accept as probable the unbroken sequence of development from the nebula to the present time.' Thus it appears that, long antecedent to the publication of his advice, I did exactly what Professor Virchow recommends, showing myself as careful as he could be not to claim for a scientific doctrine a certainty which did not belong to it.

I now pass on to the Belfast Address, and will cite at once from it the passage which has given rise to the most violent animadversion. 'Believing as I do in the continuity of nature, I cannot stop abruptly where our microscopes cease to be of use. At this point the vision of the mind authoritatively supplements that of the eye. By an intellectual necessity I cross the boundary of the experimental evidence, and discern in that "matter" which we, in our ignorance of its latent powers, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of all terrestrial life.' Without halting for a moment I go on to do the precise thing which Professor Virchow declares to be necessary. 'If you ask me,' I say, 'whether there exists the least evidence to prove that any form of life can be developed out of matter independently of antecedent life, my reply is that evidence considered perfectly conclusive by many has been adduced, and that were we to follow a common example, and accept testimony because it falls in with our belief, we should eagerly close with the evidence referred to. But there is in the true man of science a desire stronger than the wish to have his beliefs upheld; namely, the desire to have them true. And those to whom I refer as having studied this question, believing the evidence offered in favour of "spontaneous generation" to be vitiated by error, cannot accept it. They know full well that the chemist now prepares from inorganic matter a vast array of substances, which were some time ago regarded as the products solely of vitality. They are intimately acquainted with the structural power of matter, as evidenced in the phenomena of crystallisation. They can justify scientifically their *belief* in its potency, under the proper conditions, to produce organisms. But, in reply to your question, they will frankly admit their inability to point to any satisfactory experimental proof that life can be developed, save from demonstrable antecedent life.'[1]

Comparing the theory of evolution with other theories, I thus express myself: 'The basis of the doctrine of evolution consists, not in an experimental demonstration—for the subject is hardly accessible to this mode of proof—but in its general harmony with scientific thought. From contrast, moreover, it derives enormous relative strength. On the one side we have a theory, which converts the Power whose garment is seen in the visible universe into an Artificer, fashioned after the human model, and acting by broken efforts, as man is seen to act. On the other side we have the conception that all we see around us and feel within us—the phenomena of physical nature as well as those of the human mind—have their unsearchable roots in a cosmical life, if I dare apply the term, an infinitesimal span of which is offered to the investigation of man.' Among thinking people, in my opinion, this last conception has a higher ethical value than that of a personal artificer. Be that as it may, I make here no claim for the theory of evolution which can reasonably be refused.

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[1] Quoted by Clifford, 'Nineteenth Century,' 3, p. 726.

'Ten years have elapsed' said Dr. Hooker at Norwich in 1868[1] 'since the publication of "The Origin of Species by Natural Selection," and it is therefore not too early now to ask what progress that bold theory has made in scientific estimation. Since the "Origin" appeared it has passed through four English editions,[2] two American, two German, two French, several Russian, a Dutch, and an Italian edition. So far from Natural Selection being a thing of the past [the 'Athenæum' had stated it to be so] it is an accepted doctrine with almost every philosophical naturalist, including, it will always be understood, a considerable proportion who are not prepared to admit that it accounts for all Mr. Darwin assigns to it.' In the following year, at Innsbruck, Helmholtz took up the same ground.[3] Another decade has now passed, and he is simply blind who cannot see the enormous progress made by the theory during that time. Some of the outward and visible signs of this advance are readily indicated. The hostility and fear which so long prevented the recognition of Mr. Darwin by his own university have vanished, and this year Cambridge, amid universal acclamation, conferred on him her Doctor's degree. The Academy of Sciences in Paris, which had so long persistently closed its doors against Mr. Darwin, has also yielded at last; while sermons, lectures, and published articles plainly show that even the clergy have, to a great extent, become acclimatised to the Darwinian air. My brief reference to Mr. Darwin in the Birmingham Address was based upon the knowledge that such changes had been accomplished, and were still going on.

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[1] President's Address to the British Association.

[2] Published by Mr. John Murray, the English publisher of Virchow's Lecture. Bane and antidote are thus impartially distributed by the same hand.

[3] 'Noch besteht lebhafter Streit um die Wahrheit oder Wahrscheinlichkeit von Darwin's Theorie; er dreht sich aber doch eigentlich nur um die Grenzen, welche wir für die Veränderlichkeit der Arten annehmen dürfen. Dass innerhalb derselben Species erbliche Racenverschiedenheiten auf die von Darwin beschriebene Weise zu kommen können, ja dass viele der bisher als verschiedene Species derselben Gattung betrachteten Formen von derselben Urform abstammen, werden auch seine Gegner kaum leugnen.'—(*Populäre Vorträge.*)

That the lecture of Professor Virchow can, to any practical extent disturb this progress of public faith in the theory of evolution, I do not believe. That the special lessons of caution which he inculcates were exemplified by me, years before his voice was heard upon this subject, has been proved in the foregoing pages. In point of fact, if he had preceded me instead of following me, and if my desire had been to incorporate his wishes in my words, I could not have accomplished this more completely. It is possible, moreover, to draw the coincident lines still further, for most of what he has said about spontaneous generation might have been uttered by me. I share his opinion that the theory of evolution in its complete form involves the passage from matter which we now hold to be inorganic into organised matter; in other words, involves the assumption that at some period or other of the earth's history there occurred what would be now called 'spontaneous generation.' I agree with him that 'the proofs of it are still wanting.' 'Whoever,' he says, 'recalls to mind the lamentable failure of all the attempts made very recently to discover a decided support for the *generatio æquivoca* in the lower forms of transition from the inorganic to the organic world will feel it doubly serious to demand that this theory, so utterly discredited, should be in any way accepted as the basis of all our views of life.' I hold with Virchow that the failures *have* been lamentable, that the doctrine *is* utterly discredited. But my position here is so well known that I need not dwell upon it further.

With one special utterance of Professor Virchow his translator connects me by name. 'I have no objection,' observes the Professor, 'to your saying that atoms of carbon also possess mind, or that in their connection with the Plastidule company they acquire mind; only *I do not know how I am to perceive this.*' This is substantially what I had said seventeen years previously in the 'Saturday Review.' The Professor continues: 'If I explain attraction and repulsion as exhibitions of mind, as psychical phenomena, I simply throw the Psyche out of the window, and the Psyche ceases to be a Psyche.' I may say, in passing, that the Psyche that *could* be cast out of the window is not worth house-room. At this point the translator, who is evidently a man of culture, strikes in with a foot-note. 'As an illustration of Professor Virchow's meaning, we may quote the conclusion at which Doctor Tyndall arrives respecting the hypothesis of a human soul, offered as an explanation or a simplification of a series of obscure phenomena—psychical phenomena, as he calls them. "If you are content to make your soul a poetic rendering of a phenomenon which refuses the yoke of ordinary physical laws, I, for one, would not object to this exercise of ideality."'[1] Professor Virchow's meaning, I admit, required illustration; but I do not clearly see how the quotation from me subserves this purpose. I do not even know whether I am cited as meriting praise or deserving opprobrium. In a far coarser fashion this utterance of mine has been dealt with in other places: it may therefore be worth while to spend a few words upon it.

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[1] Presidential Address delivered before the Birmingham and Midland Institute, October 1, 1877. 'Fortnightly Review,' Nov. 1, 1877, p. 607.

The sting of a wasp at the finger-end announces itself to the brain as pain. The impression made by the sting travels, in the first place, with comparative slowness along the nerves affected; and only when it reaches the brain have we the fact of consciousness. Those who think most profoundly on this subject hold that a chemical change, which, strictly interpreted, is atomic motion, is, in such a case, propagated along the nerve, and communicated to the brain. Again, on feeling the sting I flap the insect violently away. What has caused this motion of my hand? The command from the brain to remove the insect travels along the motor nerves to the proper muscles, and, their force being unlocked, they perform the work demanded of them. But what moved the nerve molecules which unlocked the muscle? The sense of pain, it may be replied. But how can a sense of pain, or any other state of consciousness, make matter move? Not all the sense of pain or pleasure in the world could lift a stone or move a billiard-ball; why should it stir a molecule? Try to express the motion numerically in terms of the sensation, and the difficulty immediately appears. Hence the idea long ago entertained by philosophers, but lately brought into special prominence, that the physical processes are complete in themselves, and would go on just as they do if consciousness were not at all implicated. Consciousness, on this view, is a kind of by-product inexpressible in terms of force and motion, and unessential to the molecular changes going on in the brain.

Four years ago, I wrote thus: 'Do states of consciousness enter as links into the chain of antecedence and sequence, which gives rise to bodily actions? Speaking for myself, it is certain that I have no power of imagining such states interposed between the molecules of the brain, and influencing the transference of motion among the molecules. The thing "eludes all mental presentation." Hence an iron strength seems to belong to the logic which claims for the brain an automatic action uninfluenced by consciousness. But it is, I believe, admitted by those who hold the automaton theory, that states of consciousness are *produced* by the motion of the molecules of the brain; and this production of consciousness by molecular motion is to me quite as unpresentable to the mental vision as the production of molecular motion by consciousness. If I reject one result I must reject both. *I, however, reject neither*, and thus stand in the presence of two Incomprehensibles, instead of one Incomprehensible.' Here I secede from the automaton theory, though maintained by friends who have all my esteem, and fall back upon the avowal which occurs with such wearisome iteration throughout the foregoing pages; namely, my own utter incapacity to grasp the problem.

This avowal is repeated with emphasis in the passage to which Professor Virchow's translator draws attention. What, I there ask, is the causal connection between the objective and the subjective—between molecular motions and states of consciousness? My answer is: I do not see the connection, nor am I acquainted with anybody who does. It is no explanation to say that the objective and subjective are two sides of one and the same phenomenon. Why should the phenomenon have two sides? This is the very core of the difficulty. There are plenty of molecular motions which do not exhibit this two-sidedness. Does water think or feel when it runs into frost-ferns upon a window pane? If not, why should the molecular motion of the brain be yoked to this mysterious companion—consciousness? We can form a coherent picture of all the purely physical processes—the stirring of the brain, the thrilling of the nerves, the discharging of the muscles, and all the subsequent motions of the organism. We are here dealing with mechanical problems which are mentally presentable. But we can form no picture of the process whereby consciousness emerges, either as a necessary link, or as an accidental by-product, of this series of actions. The reverse process of the production of motion by consciousness is equally unpresentable to the mind. We are here in fact on the boundary line of the intellect, where the ordinary canons of science fail to extricate us. If we are true to these canons, we must deny to subjective phenomena all influence on physical processes. The mechanical philosopher, *as such*, will never place a state of consciousness and a group of molecules in the relation of mover and moved. Observation proves them to interact; but, in passing from the one to the other, we meet a blank which the logic of deduction is unable to fill. This, the reader will remember, is the conclusion at which I had arrived more than twenty years ago. I lay bare unsparingly the central difficulty of the materialist, and tell him that the facts of observation which he considers so simple are 'almost as difficult to be seized mentally as the idea of a soul.' I go further, and say, in effect, to those who wish to retain this idea, 'If you abandon the interpretations of grosser minds, who image the soul as a Psyche which could be thrown out of the window—an entity which is usually occupied, we know not how, among the molecules of the brain, but which on due occasion, such as the intrusion of a bullet or the blow of a club, can fly away into other regions of space—if, abandoning this heathen notion, you consent to approach the subject in the only way in which approach is possible—if you consent to make your soul a poetic rendering of a phenomenon which, as I have taken more pains than anybody else to show you, refuses the yoke of ordinary physical laws—then I, for one, would not object to this exercise of ideality.' I say it strongly, but with good temper, that the theologian, or the defender of theology, who hacks and scourges me for putting the question in this light is guilty of black ingratitude.

Notwithstanding the agreement thus far pointed out, there are certain points in Professor Virchow's lecture to which I should feel inclined to take exception. I think it was hardly necessary to associate the theory of evolution with Socialism; it may be even questioned whether it was correct to do so. As Lange remarks, the aim of Socialism, or of its extreme leaders, is to overthrow the existing systems of government, and anything that helps them to this end is welcomed, whether it be atheism or papal infallibility. For long years the Socialists saw Church and State united against them, and both were therefore regarded with a common hatred. But no sooner does a serious difference arise between Church and State, than a portion of the Socialists begin immediately to dally with the former.[1] The experience of the last German elections illustrates Lange's position. Far nobler and truer to my mind than this fear of promoting Socialism by a scientific theory which the best and soberest heads in the world have substantially accepted, is the position assumed by Helmholtz, who in his 'Popular Lectures' describes

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[1] 'Geschichte des Materialismus,' 2^{e} Auflage, vol. ii. p. 538.

Darwin's theory as embracing 'an essentially new creative thought' (einen wesentlich neuen schöpferischen Gedanken), and who illustrates the greatness of this thought by copious references to the solutions, previously undreamt of, which it offers of the enigmas of life and organisation. He points to the clouds of error and confusion which it has already dispersed, and shows how the progress of discovery since its first enunciation is simply a record of the approach of the theory towards complete demonstration. One point in this 'popular' exposition deserves especial mention here. Helmholtz refers to the dominant position acquired by Germany in physiology and medicine, while other nations have kept abreast of her in the investigation of inorganic nature. He claims for German men the credit of pursuing with unflagging and self-denying industry, with purely ideal aims, and without any immediate prospect of practical utility, the cultivation of pure science. But that which has determined German superiority in the fields referred to was, in his opinion, something different from this. Enquiries into the nature of life are intimately connected with psychological and ethical questions; and he claims for his countrymen a greater fearlessness of the consequences which a full knowledge of the truth may here carry along with it, than reigns among the enquirers of other nations. And why is this the case? 'England and France,' he says, 'possess distinguished investigators—men competent to follow up and illustrate with vigorous energy the methods of natural science; but they have hitherto been compelled to bend before social and theological prejudices, and could only utter their convictions under the penalty of injuring their social influence and usefulness. Germany has gone forward more courageously. She has cherished the trust, which has never been deceived, that complete truth carries with it the antidote against the bane and danger which follow in the train of half knowledge. A cheerfully laborious and temperate people —a people morally strong—can well afford to look truth full in the face. Nor are they to be ruined by the enunciation of one-sided theories, even when these may appear to threaten the bases of society.' These words of Helmholtz are, in my opinion, wiser and more applicable to the condition of Germany at the present moment than those which express the fears of Professor Virchow. It will be remembered that at the time of his lecture his chief anxieties were directed towards France; but France has since that time given ample evidence of her ability to crush, not only Socialists, but anti-Socialists, who would impose on her a yoke which she refuses to bear.

In close connection with these utterances of Helmholtz, I place another utterance not less noble, which I trust was understood and appreciated by those to whom it was addressed. 'If,' said the President of the British Association in his opening address in Dublin, 'we could lay down beforehand the precise limits of possible knowledge, the problem of physical science would be already half solved. But the question to which the scientific explorer has often to address himself is, not merely whether he is able to solve this or that problem; but whether he can so far unravel the tangled threads of the matter with which he has to deal, as to weave them into a definite problem at all. . . . If his eye seem dim, he must look steadfastly and with hope into the misty vision, until the very clouds wreathe themselves into definite forms. If his ear seem dull, he must listen patiently and with sympathetic trust to the intricate whisperings of Nature—the goddess, as she has been called, of a hundred voices —until here and there he can pick out a few simple notes to which his own powers can resound. If, then, at a moment when he finds himself placed on a pinnacle from which he is called upon to take a perspective survey of the range of science, and to tell us what he can see from his vantage ground; if at such a moment after straining his gaze to the very verge of the horizon, and after describing the most distant of well-defined objects, he should give utterance also to some of the subjective impressions which he is conscious of receiving from regions beyond; if he should depict possibilities which seem opening to his view; if he should explain why he thinks this a mere blind alley and that an open path; *then the fault and the loss would be alike ours if we refused to listen calmly, and temperately to form our own judgment on what we hear; then assuredly it is we who would be committing the error of confounding matters of fact with matters of opinion, if we failed to discriminate between the various elements contained in such a discourse, and assumed that they had been all put on the same footing.*'

While largely agreeing with him, I cannot quite accept the setting in which Professor Virchow places the confessedly abortive attempts to secure an experimental basis for the doctrine of spontaneous generation. It is not a doctrine 'so discredited' that some of the scientific thinkers of England accept 'as the basis of all their views of life.' Their induction is by no means thus limited. They have on their side more than the 'reasonable probability' deemed sufficient by Bishop Butler for practical guidance in the gravest affairs, that the members of the solar system which are now discrete once formed a continuous mass; that in the course of untold ages, during which the work of condensation, through the waste of heat in space, went on, the planets were detached; and that our present sun is the residual nucleus of the flocculent or gaseous ball from which the planets were successively separated. Life, as we define it, was not possible for æons subsequent to this separation. When and how did it appear? I have already pressed this question, but have received no answer.[1] If, with Professor Knight, we regard the Bible account of the introduction of life upon the earth as a poem, not as a statement of fact, where are we to seek for guidance as to the fact? There does not exist a barrier possessing the strength of a cobweb to oppose to the hypothesis which ascribes the appearance of life to that 'potency of matter' which finds expression in natural evolution.[2] This hypothesis is not without its difficulties, but they vanish when compared with those which encumber its rivals. There are various facts in science obviously connected, and whose connections we are unable to trace; but we do not think of filling the gap between them by the intrusion of a separable spiritual agent. In like manner though we are unable to trace the course of things from the nebula, when there was no life in our sense, to the present earth where life abounds, the spirit and practice of science pronounce against the intrusion of an anthropomorphic creator. Theologians must liberate and refine their conceptions or be prepared for the rejection of them by thoughtful minds. It is they, not we, who lay claim to knowledge never given to man. Our refusal of the creative hypothesis is less an assertion of knowledge than a protest against the assumption of knowledge which must long, if not always, lie beyond us, and the claim to which is a source of perpetual confusion.' At the same time, when I look with strenuous gaze into the whole problem as far as my capacities allow, overwhelming wonder is the predominant feeling. This wonder has come to me from the ages just as much as my understanding, and it has an equal right to satisfaction. Hence I say, if, abandoning your illegitimate claim to knowledge, you place, with Job, your forehead in the dust and acknowledge the authorship of this universe to be past finding out—if, having made this confession, and relinquished the views of the mechanical theologian, you desire for the satisfaction of feelings which I admit to be, in great part, those of humanity at large, to give ideal form to the Power that moves all things—it is not by me that you will find objections raised to this exercise of ideality, if it be only consciously and worthily carried out.

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[1] In the 'Apology for the Belfast Address,' the question is reasoned out.

[2] 'We feel it an undeniable necessity,' says Professor Virchow, 'not to sever the organic world from the whole, as if it were something disjoined from the whole.' This grave statement cannot be weakened by the subsequent pleasantry regarding 'Carbon & Co.'

Again, I think Professor Virchow's position, in regard to the question of *contagium animatum*, is not altogether that of true philosophy. He points to the antiquity of the doctrine. 'It is lost,' he says, 'in the darkness of the middle ages. We have received this name from our forefathers, and it already appears distinctly in the sixteenth century. We possess several works of that time which put forward *contagium animatum* as a scientific doctrine, with the same confidence, with the same sort of proof, with which the "Plastidulic soul" is now set forth.'

These speculations of our 'forefathers' will appeal differently to different minds. By some they will be dismissed with a sneer; to others they will appeal as proofs of genius on the part of those who enunciated them. There are men, and by no means the minority, who, however wealthy in regard to facts, can never rise into the region of principles; and they are sometimes intolerant of those who can. They are formed to plod meritoriously on the lower levels of thought, unpossessed of the pinions necessary to reach the heights. They cannot realise the mental act—the act of inspiration it might well be called—by which a man of genius, after long pondering and proving, reaches a theoretic conception which unravels and illuminates the tangle of centuries of observation and experiment. There are minds, it may be said in passing, who at the present moment stand in this relation to Mr. Darwin. For my part, I should be inclined to ascribe to penetration rather than to presumption the notion of a *contagium animatum*. He who invented the term ought, I think, to be held in esteem; for he had before him the quantity of fact, and the measure of analogy, that would justify a man of genius in taking a step so bold. 'Nevertheless,' says Professor Virchow, 'no one was able throughout a long time to discover these living germs of disease. The sixteenth century did not find them, nor did the seventeenth, nor the eighteenth.' But it may be urged, in reply to this, that the theoretic conjecture often legitimately comes first. It is the forecast of genius which anticipates the fact and constitutes a spur towards its discovery. If, instead of being a spur, the theoretic guess rendered men content with imperfect knowledge, it would be a thing to be deprecated. But in modern investigation this is distinctly not the case; Darwin's theory, for example, like the undulatory theory, has been a motive power and not an anodyne. 'At last,' continues Professor Virchow, 'in the nineteenth century we have begun little by little really to find *contagia animata*.' So much the more honour, I infer, is due to those who, three centuries in advance, so put together the facts and analogies of contagious disease as to divine its root and character. Professor Virchow seems to deprecate the 'obstinacy' with which this notion of a *contagium vivum* emerged. Here I should not be inclined to follow him; because I do not know, nor does he tell me, how much the discovery of facts in the nineteenth century is indebted to the stimulus derived from the theoretic discussions of preceding centuries. The genesis of scientific ideas is a subject of profound interest and importance. He would be but a poor philosopher who would sever modern chemistry from the efforts of the alchemists, who would detach modern atomic doctrines from the speculations of Lucretius and his predecessors, or who would claim for our present knowledge of contagia an origin altogether independent of the efforts of our 'forefathers' to penetrate this enigma.

Finally, I do not know that I should agree with Professor Virchow as to what a theory is or ought to be. I call a theory a principle or conception of the mind which accounts for observed facts, and which helps us to look for and predict facts not yet observed. Every new discovery which fits into a theory strengthens it. The theory is not a thing complete from the first, but a thing which grows, as it were asymptotically, towards certainty. Darwin's theory, as pointed out nine and ten years ago by Helmholtz and Hooker, was then exactly in this condition of growth; and had they to speak of the subject to-day they would be able to announce an enormous strengthening of the theoretic fibre. Fissures in continuity which then existed, and which left little hope of being ever spanned, have been since filled in, so that the further the theory is tested the more fully does it harmonise with progressive experience and discovery. We shall probably never fill all the gaps; but this will not prevent a profound belief in the truth of the theory from taking root in the general mind. Much less will it justify a total denial of the theory. The man of science who assumes in such a case the position of a denier is sure to be stranded and isolated. The proper attitude, in my opinion, is to give to the theory during the phases of its growth as nearly as possible a *proportionate* assent; and, if it be a theory which influences practice, our wisdom is to follow its probable suggestions where more than probability is for the moment unattainable. I write thus with the theory of *contagium vivum* more especially in my mind, and must regret the attitude of denial assumed by Professor Virchow towards that theory. 'I must beg my friend Klebs to pardon me,' he says, 'if, notwithstanding the late advances made by the doctrine of infectious fungi, I still persist in my reserve so far as to admit only the fungus which is really proved, while I deny all other fungi so long as they are not actually brought before me.' Professor Virchow, that is to say, will continue to deny the Germ Theory, however great the probabilities on its side, however numerous be the cases of which it renders a just cco unt, until it has ceased to be a theory at all, and has become a congeries of sensible facts. Had he said, 'As long as a single fungus of disease remains to be discovered, it is your bounden duty to search for it,' I should cordially agree with him. But by his unreserved denial he quenches the light of probability which ought to guide the practice of the medical man. Both here and in relation to the theory of evolution excess upon one side has begotten excess upon the other.

NOTE.—As might have been expected, Professor Virchow shows himself in practice far too sound a philosopher to be restricted by the canon laid down in his critique of Dr. Haeckel. In his recent discourse upon the plague, he asks and answers the question, 'What is the contagium?' in the following words:—'Et qu'est-ce que le contagium? A mon avis, l'analogie de la peste avec le charbon contagieux me parait si grande qu'il me semble possible de trouver un organisme microscopique qui contient le germe de l'affection. Mais jusqu'à présent on a peu cherché à trouver cet organisme.'—*Revue Scientifique*, March, 1879.

XVI.

THE ELECTRIC LIGHT.[1]

THE subject of this evening's discourse was proposed by our late honorary secretary.[2] That word 'late' has for me its own connotations. It implies, among other things, the loss of a comrade by whose side I have worked for thirteen years. On the other hand, regret is not without its opposite in the feeling with which I have seen him rise by sheer intrinsic merit, moral and intellectual, to the highest official position which it is in the power of English science to bestow. Well, he, whose constant desire and practice were to promote the interests and extend the usefulness of this institution, thought that at a time when the electric light occupied so much of public attention, a few sound notions regarding it, on the more purely scientific side, might, to use his own pithy expression, be 'planted' in the public mind. I am here to-night with the view of trying, to the best of my ability, to realise the idea of our friend.

In the year 1800, Volta announced his immortal discovery of the pile. Whetted to eagerness by the previous conflict between him and Galvani, the scientific men of the age flung themselves with ardour upon the new discovery, repeating Volta's experiments, and extending them in many ways. The light and heat of

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[1] A discourse delivered at the Royal Institution of Great Britain on Friday, January 17, 1879, and introduced here as the latest Fragment.

[2] Mr. William Spottiswoode, late President of the Royal Society.

For seventy years, then, we have been in possession of this transcendent light without applying it to the illumination of our streets and houses. Such applications suggested themselves at the outset, but there were grave difficulties in their way. The first difficulty arose from the waste of the carbons, which are dissipated in part by ordinary combustion, and in part by the electric transfer of matter from the one carbon to the other. To keep the carbons at the proper distance asunder regulators were devised, the earliest, I believe, by Staite, and the most successful by Duboscq, Foucault, and Serrin, who have been succeeded by Holmes, Siemens, Browning, Carré, Gramme, Lontin, and others. By such arrangements the first difficulty was practically overcome; but the second, a graver one, is probably inseparable from the construction of the voltaic battery. It arises from the operation of that inexorable law which throughout the material universe demands an eye for an eye, and a tooth for a tooth, refusing to yield the faintest glow of heat or glimmer of light without the expenditure of an absolutely equal quantity of some other power. Hence, in practice, the desirability of any transformation must depend upon the value of the product in relation to that of the power expended. The metal zinc can be burnt like paper; it might be ignited in a flame, but it is possible to avoid the introduction of all foreign heat and to burn the zinc in air of the temperature of this room. This is done by placing zinc foil at the focus of a concave mirror, which concentrates to a point the divergent electric beam, but which does not warm the air. The zinc burns at the focus with a violet flame, and we could readily determine the amount of heat generated by its combustion. But zinc can be burnt not only in air but in liquids. It is thus burnt when acidulated water is poured over it; it is also thus burnt in the voltaic battery. Here, however, to obtain the oxygen necessary for its combustion, the zinc has to dislodge the hydrogen with which the oxygen is combined. The consequence is that the heat due to the combustion of the metal in the liquid falls short of that developed by its combustion in air, by the exact quantity necessary to separate the oxygen from the hydrogen. Fully four-fifths of the total heat are used up in this molecular work, only one-fifth remaining to warm the battery. It is upon this residue that we must now fix our attention, for it is solely out of it that we manufacture our electric light.

Before you are two small voltaic batteries of ten cells each. The two ends of one of them are united by a thick copper wire, while into the circuit of the other a thin platinum wire is introduced. The platinum glows with a white heat, while the copper wire is not sensibly warmed. Now an ounce of zinc, like an ounce of coal, produces by its complete combustion in air a constant quantity of heat. The total heat developed by an ounce of zinc through its union with oxygen in the battery is also absolutely invariable. Let our two batteries, then, continue in action until an ounce of zinc in each of them is consumed. In the one case the heat generated is purely domestic, being liberated on the hearth where the fuel is burnt, that is to say in the cells of the battery itself. In the other case, the heat is in part domestic and in part foreign—in part within the battery and in part outside. One of the fundamental truths to be borne in mind is that the sum of the foreign and domestic—of the external and internal—heats is fixed and invariable. Hence, to have heat outside, you must draw upon the heat within. These remarks apply to the electric light. By the intermediation of the electric current the moderate warmth finally able to yield a magneto-electric light comparable to that of the voltaic battery. Judged by later knowledge, this first machine would be considered cumbrous and defective in the extreme; but judged by the light of antecedent events, it marked a great step forward.

Faraday was profoundly interested in the growth of his own discovery. The Elder Brethren of the Trinity House had had the wisdom to make him their 'Scientific Adviser;' and it is interesting to notice in his reports regarding the light, the mixture of enthusiasm and caution which characterised him. Enthusiasm was with him a motive power, guided and controlled by a disciplined judgment. He rode it as a charger, holding it in by a strong rein. While dealing with Holmes, he states the case of the light *pro* and *con*. He checks the ardour of the inventor, and, as regards cost, rejecting sanguine estimates, he insists over and over again on the necessity of continued experiment for the solution of this important question. His matured opinion was, however, strongly in favour of the light. With reference to an experiment made at the South Foreland on the 20th of April, 1859, he thus expresses himself:—'The beauty of the light was wonderful. At a mile off, the apparent streams of light issuing from the lantern were twice as long as those from the lower lighthouse, and apparently three or four times as bright. The horizontal plane in which they chiefly took their way made all above or below it black. The tops of the hills, the churches, and the houses illuminated by it were striking in their effect upon the eye.' Further on in his report he expresses himself thus:—'In fulfilment of this part of my duty, I beg to state that, in my opinion, Professor Holmes has practically established the fitness and sufficiency of the magneto-electric light for lighthouse purposes, so far as its nature and management are concerned. The light produced is powerful beyond any other that I have yet seen so applied, and in principle may be accumulated to any degree; its regularity in the lantern is great; its management easy, and its care there may be confided to attentive keepers of the ordinary degree of intellect and knowledge.' Finally, as regards the conduct of Professor Holmes during these memorable experiments, it is only fair to add the following remark with which Faraday closes the report submitted to the Elder Brethren of the Trinity House on the 29th of April, 1859:—'I must bear my testimony,' he says, 'to the perfect openness, candour, and honour of Professor Holmes. He has answered every question, concealed no weak point, explained every applied principle, given every reason for a change either in this or that direction, during several periods of close questioning, in a manner that was very agreeable to me, whose duty it was to search for real faults or possible objections, in respect both of the present time and the future.'[1]

Soon afterwards the Elder Brethren of the Trinity House had the intelligent courage to establish the machines of Holmes permanently at Dungeness, where the magneto-electric light continued to shine for many years.

The magneto-electric machine of the Alliance Company soon succeeded to that of Holmes, being in various ways a very marked improvement on the latter. Its currents were stronger and its light was brighter than those of its predecessor. In it, moreover, the commutator, the flashing and destruction of which were sources of irregularity and deterioration in the machine of Holmes, was, at the suggestion of M. Masson,[2] entirely abandoned; alternating currents instead of the direct current being employed. M. Serrin modified his excellent lamp with the express view of enabling it to cope with alternating currents. During the International Exhibition of 1862, where the machine was shown, M. Berlioz offered to dispose of the invention to the Elder Brethren of the Trinity House. They referred the matter to Faraday, and he replied as follows:—'I am not aware that the Trinity House authorities have advanced so far as to be able to decide whether they will require more magneto-electric machines, or whether, if they should require them, they see reason to suppose the means of their supply in this country, from the source already open to them, would not be sufficient. Therefore I do not see that at present they want to purchase a machine.' Faraday was obviously swayed by the desire to protect the interests of Holmes, who had borne the burden and heat which fall upon the pioneer. The Alliance machines were introduced with success at Cape la Hève, near Havre; and the Elder Brethren of the Trinity House, determined to have the best available apparatus, decided, in 1868, on the introduction of machines on the Alliance principle into the lighthouses at Souter Point and the South Foreland. These machines were constructed by Professor Holmes, and they still continue in operation. With regard, then, to the application of electricity to lighthouse purposes, the course of events was this: The Dungeness light was introduced on January 31, 1862; the light at La Hève on December 26, 1863, or nearly two years later. But Faraday's experimental trial at the South Foreland preceded the lighting of Dungeness by more than tw years. The electric light was afterwards established a Cape Grisnez. The light was started at Souter Poin on January 11, 1871; and at the South Foreland o

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[1] Holmes's first offer of his machine to the Trinity House bears date February 2, 1857.

[2] Du Moncel, 'l'Electricité,' August, 1878, p. 150.

January 1, 1872. At the Lizard, which enjoys the newest and most powerful development of the electric light, it began to shine on January 1, 1878.

I have now to revert to a point of apparently small moment, but which really constitutes an important step in the development of this subject. I refer to the form given in 1857 to the rotating armature by Dr. Werner Siemens, of Berlin. Instead of employing coils wound transversely round cores of iron, as in the machine of Saxton, Siemens, after giving a bar of iron the proper shape, wound his wire longitudinally round it, and obtained thereby greatly augmented effects between suitably placed magnetic poles. Such an armature is employed in the small magneto-electric machine which I now introduce to your notice, and for which the institution is indebted to Mr. Henry Wilde, of Manchester. There are here sixteen permanent horse-shoe magnets placed parallel to each other, and between their poles a Siemens armature. The two ends of the wire which surrounds the armature are now disconnected. In turning the handle and causing the armature to rotate, I simply overcome ordinary mechanical friction. But the two ends of the armature coil can be united in a moment, and when this is done I immediately experience a greatly increased resistance to rotation. Something over and above the ordinary friction of the machine is now to be overcome, and by the expenditure of an additional amount of muscular force I am able to overcome it. The excess of labour thus thrown upon my arm has its exact equivalent in the electric currents generated, and the heat produced by their subsidence in the coil of the armature. A portion of this heat may be rendered visible by connecting the two ends of the coil with a thin platinum wire. When the handle of the machine is rapidly turned the wire glows, first with a red heat, then with a white heat, and finally with the heat of fusion. The moment the wire melts, the circuit round the armature is broken, an instant relief from the labour thrown upon the arm being the consequence. Clearly realise the equivalent of the heat here developed. During the period of turning the machine a certain amount of combustible substance was oxidised or burnt in the muscles of my arm. Had it done no external work, the matter consumed would have produced a definite amount of heat. Now, the muscular heat actually developed during the rotation of the machine fell short of this definite amount, the missing heat being reproduced to the last fraction in the glowing platinum wire and the other parts of the machine. Here, then, the electric current intervenes between my muscles and the generated heat, exactly as it did a moment ago between the voltaic battery and its generated heat. The electric current is to all intents and purposes a vehicle which transports the heat both of muscle and battery to any distance from the hearth where the fuel is consumed. Not only is the current a messenger, but it is also an intensifier of magical power. The temperature of my arm is, in round numbers, 100° Fahr., and it is by the intensification of this heat that one of the most refractory of metals, which requires a heat of 3,600° Fahr. to fuse it, has been reduced to the molten condition.

Zinc, as I have said, is a fuel far too expensive to permit of the electric light produced by its combustion being used for the common purposes of life, and you will readily perceive that the human muscles, or even the muscles of a horse, would be more expensive still. Here, however, we can employ the force of burning coal to turn our machine, and it is this employment of our cheapest fuel, rendered possible by Faraday's discovery, which opens out to us the prospect of being able to apply the electric light to public use.

In 1866 a great step in the intensification of induced currents, and the consequent augmentation of the magneto-electric light, was taken by Mr. Henry Wilde. It fell to my lot to report upon them to the Royal Society, but before doing so I took the trouble of going to Manchester to witness Mr. Wilde's experiments. He operated in this way: starting from a small machine like that worked in your presence a moment ago, he employed its current to excite an electro-magnet of a peculiar shape, between whose poles rotated a Siemens armature;[1] from this armature currents were obtained vastly stronger than those generated by the small magneto-electric machine. These currents might have been immediately employed to produce the electric light; but instead of this they were conducted round a second electro-magnet of vast size, between whose poles rotated a Siemens armature of corresponding dimensions. Three armatures therefore were involved in this series of operations: first, the armature of the small magneto-electric machine; secondly, the armature of the first electro-magnet, which was of considerable size; and, thirdly, the armature of the second electro-magnet, which was of vast dimensions. With the currents drawn from this third armature, Mr. Wilde obtained effects, both as regards heat and light, enormously transcending those previously known.[2]

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[1] Page and Moigno had previously shown that the magneto-electric current could produce powerful electro-magnets.

[2] Mr. Wilde's paper is published in the 'Philosophical Transactions' for 1867, p. 89. My opinion regarding Wilde's machine was briefly expressed in a report to the Elder Brethren of the

But the discovery which, above all others, brought the practical question to the front is now to be considered. On the 4th of February, 1867, a paper was received by the Royal Society from Dr. William Siemens bearing the title, 'On the Conversion of Dynamic into Electrical Force without the use of Permanent Magnetism.'[1] On the 14th of February a paper from Sir Charles Wheatstone was received, bearing the title, 'On the Augmentation of the Power of a Magnet by the reaction thereon of Currents induced by the Magnet itself.' Both papers, which dealt with the same discovery, and which were illustrated by experiments, were read upon the same night, viz. the 14th of February. It would be difficult to find in the whole field of science a more beautiful example of the interaction of natural forces than that set forth in these two papers. You can hardly find a bit of iron—you can hardly pick up an old horse-shoe, for example—that does not

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Trinity House on May 17, 1866: 'It gives me pleasure to state that the machine is exceedingly effective, and that it far transcends in power all other apparatus of the kind.'

[1] A paper on the same subject, by Dr. Werner Siemens, was read on January 17, 1867, before the Academy of Sciences in Berlin. In a letter to 'Engineering,' No. 622, p. 45, Mr. Robert Sabine states that Professor Wheatstone's machines were constructed by Mr. Stroh in the months of July and August, 1866. I do not doubt Mr. Sabine's statement; still it would be dangerous in the highest degree to depart from the canon, in asserting which Faraday was specially strenuous, that the date of a discovery is the date of its publication. Towards the end of December, 1866, Mr. Alfred Varley also lodged a provisional specification (which, I believe, is a sealed document) embodying the principles of the dynamo-electric machine, but some years elapsed before he made anything public. His brother, Mr. Cromwell Varley, when writing on this subject in 1867, does not mention him (Proc. Roy. Soc., March 14, 1867). It probably marks a national trait, that sealed communications, though allowed in France, have never been recognised by the scientific societies of England.

possess a trace of permanent magnetism; and from such a small beginning Siemens and Wheatstone have taught us to rise by a series of interactions between magnet and armature to a magnetic intensity previously unapproached. Conceive the Siemens armature placed between the poles of a suitable electro-magnet. Suppose this latter to possess at starting the faintest trace of magnetism; when the armature rotates, currents of infinitesimal strength are generated in its coil. Let the ends of that coil be connected with the wire surrounding the electro-magnet. The infinitesimal current generated in the armature will then circulate round the magnet, augmenting its intensity by an infinitesimal amount. The strengthened magnet instantly reacts upon the coil which feeds it, producing a current of greater strength. This current again passes round the magnet, which immediately brings its enhanced power to bear upon the coil. By this play of mutual give and take between magnet and armature, the strength of the former is raised in a very brief interval from almost nothing to complete magnetic saturation. Such a magnet and armature are able to produce currents of extraordinary power, and if an electric lamp be introduced into the common circuit of magnet and armature, we can readily obtain a most powerful light.[1] By this discovery, then, we are enabled to avoid the trouble and expense involved in the employment of permanent magnets; we are also enabled to drop the exciting magneto-electric machine, and the duplication of the electro-magnets. By it, in short, the electric generator is so far simplified, and reduced in cost, as to enable electricity to enter the lists as the rival of our present means of illumination.

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[1] In 1867 Mr. Ladd introduced the modification of dividing the armature into two separate coils, one of which fed the electro-magnets, while the other yielded the induced currents.

Soon after the announcement of their discovery by Siemens and Wheatstone, Mr. Holmes, at the instance of the Elder Brethren of the Trinity House, endeavoured to turn this discovery to account for lighthouse purposes. Already, in the spring of 1869, he had constructed a machine which, though hampered with defects, exhibited extraordinary power. The light was developed in the focus of a dioptric apparatus placed on the Trinity Wharf at Blackwall, and witnessed by the Elder Brethren, Mr. Douglass, and myself, from an observatory at Charlton, on the opposite side of the Thames. Falling upon the suspended haze, the light illuminated the atmosphere for miles all round. Anything so sunlike in splendour had not, I imagine, been previously witnessed. The apparatus of Holmes, however, was rapidly distanced by the safer and more powerful machines of Siemens and Gramme.

As regards lighthouse illumination, the next step forward was taken by the Elder Brethren of the Trinity House in 1876–77. Having previously decided on the establishment of the electric light at the Lizard in Cornwall, they instituted, at the time referred to, an elaborate series of comparative experiments wherein the machines of Holmes, of the Alliance Company, of Siemens, and of Gramme, were pitted against each other. The Siemens and the Gramme machines delivered direct currents, while those of Holmes and the Alliance Company delivered alternating currents. The light of the latter was of the same intensity in all azimuths; that of the former was different in different azimuths, the discharge being so regulated as to yield a gush of light of special intensity in one direction. The following table gives in standard candles the performance of the respective machines:—[1]

Name of Machines.	Maximum.	Minimum.
Holmes	1,523	1,523
Alliance	1,953	1,953
Gramme (No. 1) . . .	6,663	4,016
Gramme (No. 2) . . .	6,663	4,016
Siemens (Large) . .	14,818	8,932
Siemens (Small, No. 1) .	5,539	3,339
Siemens (Small, No. 2) .	6,864	4,138
Two Holmes's coupled .	2,811	2,811
Two Gramme's (Nos. 1 and 2)	11,396	6,869
Two Siemens' (Nos. 1 and 2)	14,134	8,520

These determinations were made with extreme care and accuracy by Mr. Douglass, the engineer-in-chief, and Mr. Ayres, the assistant engineer of the Trinity House. It is practically impossible to compare photometrically and directly the flame of the candle with these sun-like lights. A light of intermediate intensity—that of the six-wick Trinity oil lamp—was therefore in the first instance compared with the electric light. The candle power of the oil lamp being afterwards determined, the intensity of the electric light became known. The numbers given in the table prove the superiority of the Alliance machine over that of Holmes. They prove the great superiority both of the Gramme machine and of the small Siemens machine over the Alliance. The large Siemens machine is shown to yield a light far exceeding all the others, while the passage when the number of intervals is increased. Thus, by augmenting the convolutions of our machines we sacrifice quantity and gain electro-motive force; while by lessening the number of the convolutions, we sacrifice electro-motive force and gain quantity. Whether we ought to choose the one form of machine or the other depends entirely upon the external work the machine has to perform. If the object be to obtain a single light of great splendour, machines of low resistance and large quantity must be employed. If we want to obtain in the same circuit several lights of moderate intensity, machines of high internal resistance and of correspondingly high electro-motive power must be invoked.

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[1] Observations from the sea on the night of November 21, 1876, made the Gramme and small Siemens practically equal to the Alliance. But the photometric observations, in which the external resistance was abolished, and previous to which the light-keepers had become more skilled in the management of the direct current, showed the differences recorded in the table. A close inspection of these powerful lights at the South Foreland caused my face to peel, as if it had been irritated by an Alpine sun.

When a coil of covered wire surrounds a bar of iron, the two ends of the coil being connected together, every alteration of the magnetism of the bar is accompanied by the development of an induced current in the coil. The current is only excited during the period of magnetic change. No matter how strong or how weak the magnetism of the bar may be, as long as its condition remains permanent no current is developed. Conceive, then, the pole of a magnet placed near one end of the bar to be moved along it towards the other end. During the time of the pole's motion there will be an incessant change in the magnetism of the bar, and accompanying this change we shall have an induced current in the surrounding coil. If, instead of moving the magnet, we move the bar and its surrounding coil past the magnetic pole, a similar alteration of the magnetism of the bar will occur, and a similar current will be induced in the coil. You have here the fundamental conception which led M. Gramme to the construction of his beautiful machine.[1] He aimed at giving continuous motion to such a bar as we have here described; and for this purpose he bent it into a continuous ring, which, by a suitable mechanism, he caused to rotate rapidly close to the poles of a horse-shoe magnet. The direction of the current varied with the motion and with the character of the influencing pole. The result was that the currents in the two semicircles of the coil surrounding the ring flowed in opposite directions. But it was easy, by the mechanical arrangement called a commutator, to gather up the currents and cause them to flow in the same direction. The first machines of Gramme, therefore, furnished *direct* currents, similar to those yielded by the voltaic pile. M. Gramme subsequently so modified his machine as to produce alternating currents. Such alternating machines are employed to produce the lights now exhibited on the Holborn Viaduct and the Thames Embankment.

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[1] 'Comptes Rendus,' 1871, p. 176. See also Gaugain on the Gramme machine, 'Ann. de Chem. et de Phys.,' vol. xxviii. p. 324.

Another machine of great alleged merit is that of M. Lontin. It resembles in shape a toothed iron wheel, the teeth being used as cores, round which are wound coils of copper wire. The wheel is caused to rotate between the opposite poles of powerful electro-magnets. On passing each pole the core or tooth is strongly magnetised, and instantly evokes in its surrounding coil an induced current of corresponding strength. The currents excited in approaching to and retreating from a pole, and in passing different poles, move in opposite directions, but by means of a commutator these conflicting electric streams are gathered up and caused to flow in a common bed. The bobbins, in which the currents are induced, can be so increased in number as to augment indefinitely the power of the machine. To excite his electro-magnets, M. Lontin applies the principle of Mr. Wilde. A small machine furnishes a direct current, which is carried round the electro-maghas been given to M. Rapieff to develope and simplify his invention at Printing House Square. The illumination of the press-room, which I had the pleasure of witnessing, under the guidance of M. Rapieff himself, is extremely effectual and agreeable to the eye. There are, I believe, five lamps in the same circuit, and the regulators are so devised that the extinction of any lamp does not compromise the action of the others. M. Rapieff has lately improved his regulator.

Many other inventors might here be named, and fresh ones are daily crowding in. Mr. Werdermann has been long known in connection with this subject. Employing as negative carbon a disc, and as positive carbon a rod, he has, I am assured, obtained very satisfactory results. The small resistances brought into play by his minute arcs enable Mr. Werdermann to introduce a number of lamps into a circuit traversed by a current of only moderate electro-motive power. M. Reynier is also the inventor of a very beautiful little lamp, in which the point of a thin carbon rod, properly adjusted, is caused to touch the circumference of a carbon wheel which rotates underneath the point. The light is developed at the place of contact of rod and wheel. One of the last steps, though I am informed not quite the last, in the improvement of regulators is this: The positive carbon wastes more profusely than the negative, and this is alleged to be due to the greater heat of the former. It occurred to Mr. William Siemens to chill the negative artificially, with the view of diminishing or wholly preventing its waste. This he accomplishes by making the negative pole a hollow cone of copper, and by ingeniously discharging a small jet of cold water against the interior of the cone. His negative copper is thus caused to remain fixed in space, for it is not dissipated, the positive carbon only needing control. I have seen this lamp in action, and can bear witness to its success.

I might go on to other inventions, achieved or projected. Indeed, there is something bewildering in the recent rush of constructive talent into this domain of applied electricity. The question and its prospects are modified from day to day, a steady advance being made towards the improvement both of machines and regulators. With regard to our public lighting, I strongly lean to the opinion that the electric light will at no distant day triumph over gas. I am not so sure that it will do so in our private houses. As, however, I am anxious to avoid dropping a word here that could influence the share market in the slightest degree, I limit myself to this general statement of opinion.

To one inventor in particular belongs the honour of the idea, and the realisation of the idea, of causing the carbon rods to burn away like a candle. It is needless to say that I here refer to the young Russian officer, M. Jablochkoff. He sets two carbon rods upright at a small distance apart, and fills the space between them with an insulating substance like plaster of Paris. The carbon rods are fixed in metallic holders. A momentary contact is established between the two carbons by a little cross-piece of the same substance placed horizontally from top to top. This cross-piece is immediately dissipated or removed by the current, the passage of which once established is afterwards maintained. The carbons gradually waste, while the substance between them melts like the wax of a candle. The comparison, however, only holds good for the act of melting; for, as regards the current, the insulating plaster is practically inert. Indeed, as proved by M. Rapieff and Mr. Wilde, the plaster may be dispensed with altogether, the current passing from point to point between the naked carbons. M. de Méritens has recently brought out a new candle, in which the plaster is abandoned, while between the two principal carbons is placed a third insulated rod of the same material. With the small de Méritens machine two of these candles can be lighted before you; they produce a very brilliant light.[1] In the Jablochkoff candle it is necessary that the carbons should be consumed at the same rate. Hence the necessity for alternating currents by which this equal consumption is secured. It will be seen that M. Jablochkoff has abolished regulators altogether, introducing the candle principle in their stead. In my judgment, the performance of the Jablochkoff candle on the Thames Embankment and the Holborn Viaduct is highly creditable, notwithstanding a considerable waste of light towards the sky. The Jablochkoff lamps, it may be added, would be more effective in a street, where their light would be scattered abroad by the adjacent houses, than in the positions which they now occupy in London.

It was my custom some years ago, whenever I needed a new and complicated instrument, to sit down beside its proposed constructor, and to talk the matter over with him. The study of the inventor's mind which this habit opened out was always of the highest interest to me. I particularly well remember the impression made upon me on such occasions by the late Mr. Darker, a philosophical instrument maker in Lambeth. This man's life was a struggle, and the reason of it was not far to seek. No matter how commercially lucrative the work upon which he was engaged might be, he would instantly turn aside from it to seize and realise the ideas of a scientific man. He had an inventor's power, and an inventor's delight in its exercise. The late Mr. Becker possessed the same power in a very considerable degree. On the Continent, Froment, Breguet, Sauerwald, and others might be mentioned as eminent instances of ability of this kind. Such minds resemble a liquid on the point of crystallisation. Stirred by a hint, crystals of constructive thought immediately shoot through them. That Mr. Edison possesses this intuitive power in no common measure, is proved by what he has already accomplished. He has the penetration to seize the relationship of facts and principles, and the art to reduce them to novel and concrete combinations. Hence, though he has thus far accomplished nothing that we can recognise as new in relation to the electric light, an adverse opinion as to his ability to solve the complicated problem on which he is engaged would be unwarranted.

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[1] The machine of M. de Méritens and the Farmer-Wallace machine were worked by an excellent gas-engine, lent for the occasion by the Messrs. Crossley, of Manchester. The Siemens machine was worked by steam.

I will endeavour to illustrate in a simple manner Mr. Edison's alleged mode of electric illumination, taking advantage of what Ohm has taught us regarding the laws of the current, and what Joule has taught us regarding the relation of resistance to the development of light and heat. From one end of a voltaic battery runs a wire, dividing at a certain point into two branches, which reunite in a single wire connected with the other end of the battery. From the positive end of the battery the current passes first through the single wire to the point of junction, where it divides itself between the branches according to a well-known law. If the branches be equally resistant, the current divides itself equally between them. If one branch be less resistant than the other, more than half the current will choose the freer path. The strict law is that the quantity of current is inversely proportional to the resistance. A clear image of the process is derived from the deportment of water. When a river meets an island it divides, passing right and left of the obstacle, and afterwards reuniting. If the two branch beds be equal in depth, width, and inclination, the water will divide itself equally between them. If they be unequal, the larger quantity of water will flow through the more open course. And, as in the case of the water we may have an indefinite number of islands, producing an indefinite subdivision of the trunk stream, so in the case of electricity we may have, instead of two branches, any number of branches, the current dividing itself among them, in accordance with the law which fixes the relation of flow to resistance.

Let us apply this knowledge. Suppose an insulated copper rod, which we may call an 'electric main,' to be laid down along one of our streets, say along the Strand. Let this rod be connected with one end of a powerful voltaic battery, a good metallic connection being established between the other end of the battery and the water-pipes under the street. As long as the electric main continues unconnected with the water-pipes, the circuit is incomplete and no current will flow; but if any part of the main, however distant from the battery, be connected with the adjacent water-pipes, the circuit will be completed and the current will flow. Supposing our battery to be at Charing Cross, and our rod of copper to be tapped opposite Somerset House, a wire can be carried from the rod into the building, and the current passing through the wire may be subdivided into any number of subordinate branches, which reunite afterwards and return through the water-pipes to the battery. The branch currents may be employed to raise to vivid incandescence a refractory metal like iridium or one of its alloys. Instead of being tapped at one point, our main may be tapped at one hundred points. The current will divide in strict accordance with law, its power to produce light being solely limited by its strength. The process of division closely resembles the circulation of the blood; the electric main carrying the outgoing current representing a great artery, the water-pipes carrying the return current representing a great vein, while the intermediate branches represent the various vessels by which the blood is distributed through the system. This, if I understand aright, is Mr. Edison's proposed mode of illumination. The electric force is at hand. Metals sufficiently refractory to bear being raised to vivid incandescence are also at hand. The principles which regulate the division of the current and the development of its light and heat are perfectly well known. There is no room for a 'discovery,' in the scientific sense of the term, but there is ample room for the exercise of that mechanical ingenuity which has given us the sewing machine and so many other useful inventions. Knowing something of the intricacy of the practical problem, I should certainly prefer seeing it in Mr. Edison's hands to having it in mine.[1]

It is sometimes stated as a recommendation to the electric light, that it is light without heat; but to disprove this, it is only necessary to point to the experiments of Davy, which show that the heat of the voltaic arc transcends that of any other terrestrial source. The emission from the carbon points is capable of accurate analysis. To simplify the subject, we will take the case of a platinum wire at first slightly warmed by the current, and then gradually raised to a white heat. When first warmed, the wire sends forth rays which have no power on the optic nerve. They are what we call invisible rays; and not until the temperature of the wire has reached nearly 1,000° Fahr., does it begin to glow with a faint, red light. The rays which it emits prior to redness are all invisible rays, which can warm the hand but cannot excite vision. When the temperature of the wire is raised to whiteness, these dark rays not only persist, but they are enormously augmented in intensity. They constitute about 95 per cent. of the total radiation from the white-hot platinum wire. They make up nearly 90 per cent. of the emission from a brilliant electric light. You can by no means have the light of the carbons without this invisible emission as an accompaniment. The visible radiation is, as it were, built upon the invisible as its necessary foundation.

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[1] More than thirty years ago the radiation from incandescent platinum was admirably investigated by Dr. Draper of New York.

It is easy to illustrate the growth in intensity of these invisible rays as the visible ones enter the radiation and augment in power. The transparency of the elementary gases and metalloids—of oxygen, hydrogen, nitrogen, chlorine, iodine, bromine, sulphur, phosphorus, and even of carbon, for the invisible heat rays is extraordinary. Dissolved in a proper vehicle, iodine cuts the visible radiation sharply off, but allows the invisible free transmission. By dissolving iodine in sulphur, Professor Dewar has recently added to the number of our effectual ray-filters. The mixture may be made as black as pitch for the visible, while remaining transparent for the invisible rays. By such filters it is possible to detach the invisible rays from the total radiation, and to watch their augmentation as the light increases. Expressing the radiation from a platinum wire when it first feels warm to the touch—when, therefore, all its rays are invisible—by the number 1, the invisible radiation from the same wire raised to a white heat may be 500 or more.[1] It is not, then, by the diminution or transformation of the non-luminous emission that we obtain the luminous; the heat rays maintain their ground as the necessary antecedents and companions of the light rays. When detached and concentrated, these powerful heat rays can produce all the effects ascribed to the mirrors of Archimedes at the siege of Syracuse. While incompetent to produce the faintest glimmer of light, or to affect the most delicate air-thermometer, they will inflame paper, burn up wood, and even ignite combustible metals. When they impinge upon a metal refractory enough to bear their shock without fusion, they can raise it to a heat so white and luminous as to yield, when analysed, all the colours of the spectrum. In this way the dark rays emitted by the incandescent carbons are converted into light rays of all colours. Still, so powerless are these invisible rays to excite vision, that the eye has been placed at a focus competent to raise platinum foil to bright redness, without experiencing any visual impression. Light for light, no doubt, the amount of heat imparted by the incandescent carbons to the air is far less than that imparted by gas flames. It is less, because of the smaller size of the carbons, and of the comparative smallness of the quantity of fuel consumed in a given time. It is also less because the air cannot penetrate the carbons as it penetrates a flame. The temperature of the flame is lowered by the admixture of a gas which constitutes four-fifths of our atmosphere, and which, while it appropriates and diffuses the heat, does not aid in the combustion; and this lowering of the temperature by the inert atmospheric nitrogen, renders necessary the combustion of a greater amount of gas to produce the necessary light. In fact, though the statement may appear paradoxical, it is entirely because of its enormous actual temperature that the electric light seems so cool. It is this temperature that renders the proportion of luminous to non-luminous heat greater in the electric light than in our brightest flames. The electric light, moreover, requires no air to sustain it. It glows in the most perfect air vacuum. Its light and heat are therefore not purchased at the expense of the vitalising constituent of the atmosphere.

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[1] See article 'Radiation,' vol. i.

Two orders of minds have been implicated in the development of this subject; first, the investigator and discoverer, whose object is purely scientific, and who cares little for practical ends; secondly, the practical mechanician, whose object is mainly industrial. It would be easy, and probably in many cases true, to say that the one wants to gain knowledge, while the other wishes to make money; but I am persuaded that the mechanician not unfrequently merges the hope of profit in the love of his work. Members of each of these classes are sometimes scornful towards those of the other. There is, for example, something superb in the disdain with which Cuvier hands over the discoveries of pure science to those who apply them: 'Your grand practical achievements are only the easy application of truths not sought with a practical intent—truths which their discoverers pursued for their own sake, impelled solely by an ardour for knowledge. Those who turned them into practice could not have discovered them, while those who discovered them had neither the time nor the inclination to pursue them to a practical result. Your rising workshops, your peopled colonies, your vessels which furrow the seas; this abundance, this luxury, this tumult,'—'this commotion,' he would have added, were he now alive, 'regarding the electric light'—'all come from discoverers in Science, though all remain strange to them. The day that a discovery enters the market they abandon it; it concerns them no more.'

In writing thus, Cuvier probably did not sufficiently take into account the reaction of the applications of science upon science itself. The improvement of an old instrument or the invention of a new one is often tantamount to an enlargement and refinement of the senses of the scientific investigator. Beyond this, the amelioration of the community is also an object worthy of the best efforts of the human brain. Still, assuredly it is well and wise for a nation to bear in mind that those practical applications which strike the public eye, and excite public admiration, are the outgrowth of long antecedent labours begun, continued, and ended, under the operation of a purely intellectual stimulus. 'Few,' says Pasteur, 'seem to comprehend the real origin of the marvels of industry and the wealth of nations. I need no other proof of this than the frequent employment in lectures, speeches, and official language of the erroneous expression, "applied science." A statesman of the greatest talent stated some time ago that in our day the reign of theoretic science had rightly yielded place to that of applied science. Nothing, I venture to say, could be more dangerous, even to practical life, than the consequences which might flow from these words. They show the imperious necessity of a reform in our higher education. There exists no category of sciences to which the name of "applied science" could be given. We have science and the applications of science which are united as tree and fruit.'

A final reflection is here suggested. We have amongst us a small cohort of social regenerators—men of high thoughts and aspirations—who would place the operations of the scientific mind under the control of a hierarchy which should dictate to the man of science the course that he ought to pursue. How this hierarchy is to get its wisdom they do not explain. They decry and denounce scientific theories; they scorn all reference to ether, and atoms, and molecules, as subjects lying far apart from the world's needs; and yet such ultra-sensible conceptions are often the spur to the greatest discoveries. The source, in fact, from which the true natural philosopher derives inspiration and unifying power is essentially ideal. Faraday lived in this ideal world. Nearly half a century ago, when he first obtained a spark from the magnet, an Oxford don expressed regret that such a discovery should have been made, as it placed a new and facile implement in the hands of the incendiary. To regret, a Comtist hierarchy would have probably added repression, sending Faraday back to his bookbinder's bench as a more dignified and practical sphere of action than peddling with a magnet. And yet it is Faraday's spark which now shines upon our coasts, and promises to illuminate our streets, halls, quays, squares, warehouses, and, perhaps at no distant day, our homes.

THE END.

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